Although not spread upon the record until the current 1949-50 color hearing record (Tr. 7941), Donald Fink had written in the January 1947 Electronics Magazine:

> "The sequential and simultaneous systems have been referred to as mechanical and electronic systems, respectively, but these are not significant designations, since either system can be operated electronically." (Electronics Magazine, January 1947, page 72).

Mr. Fink was a member of RMA and RTPB television industry technical committees which were concerned with engineering presentations in the 1946-47 color hearing.

Du Mont's Dr. T. T. Goldsmith recognized that the field sequential system was an electronic system and actually described the triphosphor tube in the context of being equally applicable to color switching by fields, or to simultaneous transmission of each color on separate channels. He said:

> "The Trichromoscope tube may be employed with either simultaneous transmission color systems, or sequential transmission color systems, giving the highest brightness with the simultaneous system. It provides the advantage or direct viewing in full color by all-electronic means.
>
> "Further tubes of this Trichromoscope type are being constructed, using the triangular pyramid structure impressed directly on the glass at the front of the [fol. 236] tube. With the pyramidal impression it is a simple matter to settle the phosphors in turn on the three sets of faces corresponding to red, blue, and green, respectively." (Docket 7896, p. 1448-50).

Under such circumstances, there was no reason for the Commission to have been misled by continuous reference in the 1946-47 color record to field sequential color as mechanical. Nevertheless, the assumption that the CBS system is mechanical was continually made by the industry which, on the other hand, repeatedly referred to the ill-fated simultaneous system as an all electronic system. This continuous use of the term "all electronic" raised the obvious inference that the field sequential system was not all electronic and was therefore inferior. In fact, Dr. Du

Mont in 1947 implied that a field sequential system could not be all electronic:

> "All electronic color television systems are now under development by several companies. These systems may allow transmission of color television, *not in color sequence by fields*, but in color sequence by picture elements, or by picture lines, or possibly even by simultaneous transmission of all three colors.
>
> "We therefore believe that it is far too early to consider standardizing on a scanning system which is an outgrowth of obsolete mechanical color filters, when electronic developments in color may make it possible in a few years to provide excellent color television free from this fatiguing flicker and cold breakup." (Emphasis supplied.) (Docket 7896, p. 1425-6).

Dr. Engstrom at the same time confused the issue with a little different approach. He claimed that if you made the field sequential system all electronic you practically had a simultaneous system. He said:

> "I am not saying now that one can't do the sequential method electronically, but if you do the sequential method electronically, it isn't much of a step to make it simultaneous, and I think there are some real substantial advantages in doing that." (Docket 7896, pp. 1213-14).

This testimony is clearly erroneous because by no stretch of the imagination can a color system transmitting its color sequentially be the same as one which transmits its color simultaneously on three separate channels. Therefore, Dr. Engstrom could only have been talking about the effect of utilizing equipments making the field sequential system simulate a simultaneous system so far as the receiver is concerned. He could only have had in mind the use of triphosphor tube or three tubes each with a different colored phosphor, which would have the effect at the receiver of simultaneous transmission of the three colors on the television screen. That is to say, if the phosphors, on the single tube or the three tubes, were long persistent the eye would be fooled by the persistence of each color on the screen simulating a full color picture constantly. Dr.

Engstrom, however, did not want to support Dr. Goldmark that when three tubes were used, or when a triphosphor tube was built with long persistent phosphors, the sequential system's alleged flicker problem would be solved. To do [fol. 227] so would have pulled the props from the no-color-now case in 1947.

Testimony such as Dr. Du Mont's and Dr. Engstrom's may have been responsible for the Commission statement in its 1947 decision that "unless and until such a *system* which has the three tube *system* is constructed and field tested, there is no assurance it will work successfully." The Commission lost sight completely of the field sequential, system potentiality when it transposed equipments with systems as synonymous terms. This misconcepetion, fed by Drs. Du Mont and Engstrom and the rest of the industry, led the Commission to recite timidly an elemental fact:

> "Dr. Goldmark testified that the color wheel was not an integral part of the sequential system." (11 FCC 1533).

The Commission, therefore, decided that it

> "could not assume with any degree of assurance" that the field sequential system "is not limited by the color wheel." (11 FCC 1533).

The employment of three tubes each with a phosphor of one of the three primary colors was an equipment problem, *not a system problem.* The FCC had one system being urged for standardization; had it recognized in 1947 as did Fink and Goldsmith that the field sequential system was as electronic a system as the simultaneous system, the Commission might not have fallen into the trap of deferring color on the foregoing ground to await the development of a simultaneous system that never had a successful broadcast. Indeed, there was justification, if proper interpretation of the testimony on this point had been made, to have adopted the field sequential system on the basis of its brightness potential utilizing three-tube receivers.[8]

At least the industry should have been taught three years ago that it could not confuse the Commission by such sham

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[8] The CBS system was, of course, made the subject of public reaction tests viewed on the disc receivers in 1947.

engineering testimony. The industry, however, liked this argument; the 9,700 pages of the current 1949-50 color hearing record is filled again with this misconception regarding the field sequential system. Throughout the record switching the three primary colors by picture elements (dot sequential system) and by lines (line sequential system) are referred to as all electronic systems, while again history is repeating itself—the field sequential system is referred to as the mechanical system.

To start with, JTAC in its testimony represented to the Commission that it was concerned solely with the ultimate system potentialities of each of the color systems it discussed. It claimed that it did not involve itself with matters of apparatus. Nevertheless, in referring to the [fol. 228] CBS system, it limited the CBS system to operation with a disc. Upon cross-examination Mr. Fink admitted that the JTAC table had confused the matter of apparatus with that of system insofar as its report indicated that the field sequential system was limited by the disc. (Tr. 7942-4).

Likewise, Raymond Cosgrove, president of the Radio Manufacturers Association, apparently did not understand the difference between the disc as a matter of apparatus as compared with a system limitation in the field sequential system. In discussing at the beginning of the hearing the possibility of converting existing black and white receivers so that they could receive color, it did not occur to him that any electronic apparatus could be used by the field sequential system. On the contrary, he referred repeatedly to the difference between the all-electronic system as compared with the field sequential system. Some of his testimony is as follows:

> "Now, I don't think manufacturers would stand for a major cost of a conveyor (sic) at the expense of a minor modification of an existing receiver. Our supposition and the information which we have—and I admit it is quite incomplete—indicates that the adapter of the *electronic system* can be made as low in cost as the mechanical adapter. Now, if it can—and with some reservation to mechanical means of doing it and some degrading of the information because of the slower action of it to fool the eye, as I understand it—and I may be getting over my depth in the next sentence—that

the feeling of the manufacturers, reflected in here, is that this adapter on the electronic basis can be made as low in cost as the mechanical adapter." (Emphasis supplied.) (Tr. p. 2247).

General Sarnoff suffered from this same basic engineering fallacy. He was questioned at length concerning his testimony that the field sequential system was built around the disc. Upon questioning by the Chairman, he said:

"The Chairman: But you do say that the disc is the thing that causes you to say that the CBS system is a mechanical system?

"The Witness: That is right.

"The Chairman: And when they eliminate that, if they get a system that works, you would call that an all-electronic?

"The Witness: I would." (Tr. 10323).

When confronted with this misleading distinction, Dr. Engstrom admitted its engineering invalidity but still felt it was proper to call the CBS system mechanical. The following appears in the record:

"Commissioner Jones: There is one further thing, too, in reference to several of the press releases and exchanges between Dr. Stanton and General Sarnoff, press releases, and I believe one press release was [fol. 229] issued by Mr. Jolliffe, distinguishing between —the distinguishing feature of which is between the field sequential and the dot sequential system, which was that one was mechanical and the other was electronic.

"Do you believe that is a fair appraisal of the situation?

"The Witness: To the extent that they have been demonstrated, but not to the extent to which they might be set up.

"Commissioner Jones: Don't you think that beclouds the issue here as to what is involved before the Commission? Both of them are all electronic, or both of them can use three tubes, or both of them can use or all three of them could use your single tube?

"The Witness: I don't for this reason, Commissioner: This one party, CBS by name, has proposed

that the virtue of its system is the low cost, and in their terms, low amount of complexity of the color disc.

"Commissioner Jones: Do you agree—you don't agree, as an engineer, however, that it is basically a mechanical system? Don't you think that gives the wrong connotation to an unsuspecting public?

"The Witness: It doesn't need to be, but the party has not presented it in any other form.

"Commissioner Jones: Well, let us get it this way:

"You don't describe a thing scientifically—as a matter of fact, didn't JTAC make a complete presentation of eight or nine systems here on the basis of not considering any terminal equipment at all?

"The Witness: Not considering—you mean——

"Commissioner Jones: Any terminal equipment, in their tables in analyzing the different systems that might be available.

"The Witness: Of the one committee of RMA that met on the subject, they analyzed the performance of the system, based on what could be obtained in the channel width from certain standards.

"Commissioner Jones: Theoretical:

"The Witness: That is right, that is correct.

"Commissioner Jones: All right.

[fol. 230] "The Witness: But theoretically is almost potential.

"Commissioner Jones: All right.

"From an engineering standpoint, if that concept is correct, isn't it taking a backward step, engineeringwise, to consider a distinguishing feature where the one is a mechanical feature or an electronic feature?

"The Witness: It is on element, but in a procedure of this kind, I suppose it is perfectly proper when a party makes one approach, and we make the approach that we have an electronic system, that in the camera we have three camera tubes, and the party calls attention to the fact that we have a registration problem, isn't it perfectly logical and fair that we should say, 'Yes, you say you have a mechanical system' • • • 'You have an electronic system, but you have only demonstrated a mechanical system.'

"Commissioner Jones: Don't you think it would be better to clear the issues so that the public may be

advised to call them as you see them, and each pointing up their Achilles' heels, as they are, instead of dragging a shibboleth out?

"The Witness: I would like that better, certainly." (Tr. 7888-90).

Once and for all, there is no reason for the Commission to hold up a color decision in the present hearing for the false reason that field sequential is a mechanical system. From a consideration of systems, if the systems can be appraised presently and potentially with any equipments which demonstrate their system's worth, there is no justification to require a particular receiver equipment to be utilized before standards are adopted, as long as satisfactory pictures have been produced. CBS has demonstrated its system on receivers with mechanical filters and on non-mechanical tri-phosphor tubes. The tubes on the CBS projection set have the same phosphor decay coefficients as the single direct-view tube of RCA. Even the opponents of field sequential color have agreed that the RCA tri-phosphor tube will work as well on the field sequential color system. From a systems standpoint, whether a mechanical, a projection, or a direct-view single tri-phosphor tube is used is of no more consequence to the Commission's final decision than the finish of the receiving cabinet, and certainly not more than the installation of the continuous or snap tuning of channels in the receiver.

[fol. 231] Picture Brightness

There is no definitive record on this subject prior to 1946 with reference to color television specifically. In the 1941 hearing the question was considered with reference to frame rate and flicker problems which will be discussed under those subjects hereinafter. However, prior to this time no one had produced a black and white picture bright enough to involve any of those problems during that period. Black and white reception was a very dim affair then.

By 1947, however, the brightness of colo. pictures was a major issue in the color hearing on Columbia's petition. In the March 18, 1947, decision, the Commission said:

"The brightness with which a picture can be produced on a television screen is one of the most impor-

tant performance characteristics of a television receiver." (11 FCC 1527)

The Commission considered this question strictly on a demonstrated basis. It rejected all theoretical calculations or future potential of the sequential system proposed by Columbia.

Thus it rejected Columbia's evidence of laboratory performance of its system in 1947 as follows:

> "Dr. Peter C. Goldmark . . . stated that Columbia had developed a receiver in its laboratory which was capable of producing 22 footlamberts of illumination. *However, at the hearing in New York, none of its receivers developed more than 15 foot lamberts.*" (Emphasis supplied) (11 FCC 1527)

Again the industry intermixed systems considerations with equipment limitations of the time (1946-1947). The industry judged the CBS system from a purely available equipment point of view. RCA's tactics were clearly representative of industry tactics. Ray D. Kell for RCA testified as follows:

> "Picture Brightness: A mixture of phosphors producing white light is used in the kinescope for the mechanical sequential projection receiver.
>
> "The color is then achieved by placing a rotating filter disc in front of the kinescope. This disc reduces the light output by a factor of approximately eight times. From previous testimony, I believe that should be changed to ten times." (Docket 7896, pp. 729-30)

When he described RCA's simultaneous receiver he multiplied the light potential of the simultaneous system by a factor of three because there are three tubes utilized, each coated with phosphors of one of the three primary colors:

> [fol. 232] "In a simultaneous receiver this loss of light does not occur, since each of the three kinescopes has the most efficient phosphor for producing only its own color and operates without filters, except a low-loss trimmer filter on the red.
>
> "In addition, the simultaneous receiver has three kinescopes operating all the time, each contributing to

> the total light, instead of one, as in the sequential receiver. This results in an additional advantage of three to one in favor of the simultaneous system, under present operating conditions." (Docket 7896, pp. 729-30)

Nowhere did he point out that CBS could use the same three-tube apparatus that RCA used.

To dramatize to the point of burlesque their fallacious reasoning, that color was on the horizon of brighter television pictures, the Du Mont company demonstrated a black and white set alongside the 15 foot lambert Columbia color sets. The Commission's decision of 1947 describes what the industry represented was the trend in black and white television brightness.

> "In contrast, Allen B. Du Mont Laboratories, Inc., demonstrated black and white direct-view receivers that produced an average highlight brightness as high as 750 feet lamberts and Philco Radio Corp. displayed a projection type of receiver which produced an average highlight brightness of approximately 35-foot lamberts." (11 FCC 1527)

But in the 1949-50 hearing Dr. Du Mont admitted that the black and white system had no need for brightnesses of 750 foot lamberts. He said:

> "No, we never said we needed it. We did show a receiver with 750 foot lamberts, but we never said that that was necessary," (Tr. 9504)

In addition, the Commission was unsound in giving any weight whatsoever to this abnormal representation of what the highlight brightness would be in black and white receivers in the immediate future. The 1949-50 color hearing record shows that three years later the average maximum highlight brightness of black and white receivers for sale of dealers' floors is 17-foot lamberts as measured by John V. L. Hogan, Chairman of 1950 NTSC allocations Committee. (Tr. 9916) 417 readings by Hogan showed:

> ".7 percent had illumination between 4 and 6 foot lamberts. On the right-hand side also happens to be .7 percent, the last step between 28 and 30 foot lam-

berts. The largest percentage was found—in a 2 foot lambert step was found between 18 and 20 foot lamberts, where 22.3 percent of the sets are." (TR.8876)

[fol. 233] And in the 1949-50 hearing record Du Mont's T. T. Goldsmith testified on cross-examination that 52 foot lamberts was the maximum highlight brightness for a Sussex receiver—a luxury receiver which would have a much greater brightness than most receivers in the hands of the public.

Paramount Pictures, Inc., likewise joined in appraising the brightness potential of the field sequential system with contemporary equipment. Paul Raiburn of Paramount leveled his guns at the disc of CBS receivers. He testified:

> "But above all the primary requirement of a high light level seems to render completely unsatisfactory *any system* of television which throws away 90 per cent of the available light as does the proposed sequential color disc system." (Emphasis supplied) (Docket 7896, p. 1304)

Philco's David B. Smith followed the same line typing the potential of the field sequential system to the 15 foot lamberts obtained on receivers demonstrated on the record with a disc. First he described the tendency toward brighter black and white pictures. He saw improvements in technology of black and white screens but he saw no development of slow decay phosphors of the three primary colors for color television. He developed his double standard of improvement in equipments for black and white and none for color as follows:

> "The point we want to make is just this, that in the last five years there have been a substantial series of developments, all heading towards brighter pictures. We do not regard this picture as bright enough by any manner or means, and we hope to make it brighter. But in the last five years we have seen improvements in the technology of screen materials which has raised their efficiency by factors 4 and 5 times, seen the development of high gain screens, increased projection, which has further increased the bright factor 4 or 5 times.

"In our opinion, this development is not going to stop at this time. We think it not unreasonable, within the next two or three or five years, that there will be similar improvements in the art which will eventually get pictures in our living room as bright as we really want. Now, when you stop to think that the view from your window may well run into several thousand foot-lamberts, it seems a little silly to us to tie the thing down to a system that has to limp along in semi-darkened rooms, substantially completely dark, as they were in New York Monday." (Docket 7896, p. 1253)

The Commission in the March 18, 1947, decision, denying standards for field sequential color concluded with reference to brightness:

[fol. 234] "4. The Commission is of the opinion that on a question as to just how much brightness is n-cessary for home viewing under normal ambient ligting conditions, there is no substitute for actual tests in homes under a wide variety of circumstances. It is not possible to theorize on what the public will find to be generally acceptable. Adequate tests must be made at numberous home receiving locations. In many homes, the space is so arranged that lights from windows or from lamps or overhead lights will, unavoidably fall directly on the face of the receiver, being just as bad or worse than the conditions in the hearing room. Moreover, receivers will undoubtedly be placed in public places, such as auditoriums, hotel lobbies, etc. Tests should cover this type of situation as well as more ideal test situations. Until a sufficient number of tests has been made, the Commission is unable to conclude that the brightness of the Columbia picture is adequate for home use." (11 FCC 1528)

The Commission, in making this conclusion with reference to brightness, lost sight of the fact that as early as September 1940 the engineers of the industry by a vote of 33 to 4 decided that the brightness of the color demonstrated by CBS was in their estimates acceptable. It is most important that when this demonstration took place in 1940, the highlight brightness of the CBS pictures was about 2.5 foot lamberts. (Tr. pp. 2505, 3162) The Commission accepted

the testimony of the industry engineers in 1947 that the 15 foot lamberts demonstrated by the Columbia system in New York were not sufficiently bright for commercial television service. At the same time, they judged a potential highlight brightness capacity of the sequential system on the basis of the effective highlight brightness of the disc receivers demonstrated. It appears clearly that they swallowed hook, line, and sinker the criterion used by the industry that the field sequential system was limited in effective highlight brightness by the disc. Furthermore, it never occurred to the Commission that the utilization of three tubes each coated with primary phosphors as described by Kell as an integral part of the simultaneous system might also be used by the field sequential system to appraise the effective highlight brightness of that system.

In the foregoing, the Commission was unsound from a technical standpoint in judging the field sequential system highlight brightness potentials. It is demonstrated in the current hearing record that they lacked imagination with reference to appraising the field sequential system's brightness potential. Exhibit 211 shows schematically that the CBS system can use any electronic device or receiver that the simultaneous, the dot sequential, and the line sequential systems can use.

The record makes clear that so far as the existing disc receiver is concerned, adequate brightness, is achieved. Thus, Dr. Judd, of the National Bureau of Standards, in discussing the superioity of the CBS pictures over those demonstrated by other proponents, stated that this superiority "consisted in clear pictures, *adequate brightness*, and freedom from any misregistration." (Tr. 9315) (Emphasis [fol. 235] supplied) Furthermore, Exhibit 276, filed by Du Mont, states that disc type receivers in the field sequential system achieve acceptable brightness (Tr. 5737). This exhibit states: "Direct view color receivers of a mechanical type have acceptable brightness". Dr. Du Mont, visibly embarrassed by this statement, repudiated this engineering representation of his own laboratory. (Tr. 9562-63)

In addition to the testimony of Dr. Judd and the Du Mont exhibit, the public reaction tests conducted both by Dr. Dunlap and CBS itself establish beyond any doubt that the brightness of existing disc receivers is completely satisfactory to the American public. As a matter of fact, if any-

thing, the brightnesses are too high already. The Dunlap survey specifically discloses 75% of those interviewed thought the brightness was "just about right", 23% throught the pictures were too bright, and only 1½% felt that the pictures were not bright enough. (Tr. 6316) The Columbia survey indicated that color pictures of 7 to 9 foot lamberts and from 15 to 25 foot lamberts with ambient illumination varying from 1 to 7 foot candles were considered as having the right amount of brightness by more than half of the viewers. 44.9% rated such color pictures as too bright (with 40.9 limiting this by stating, "a litfle too bright") and only 1.1% stating that the pictures were a little too dim.

In addition, the field sequential color system has been demonstrated in this record to be able to produce brightness much higher than that having overwhelming acceptance in the public reaction tests. There is no limit within the framework of an acceptable broadcast service for the operation of the field sequential color system. Brightnesses of the magnitude of which the field sequential system is capable are in fact wholly unnecessary, however, for a broadcast service, as will be discussed hereafter under the subject of flicker.

[fol. 236] *Contrast*

In its March 18, 1947, decision, the Commission gave no weight to the relationship of effective brightness to contrast. It was not sure enough of the scientific principle to assert it as a finding. The Commission contented itself with the following:

> "Dr. Goldmark testified that these differences in brightness were not significant because in his opinion the brightness of the Columbia picture was adequate and that the added brightness was, therefore, not necessary. Moreover, according to Dr. Goldmark, once adequate brightness has been provided for, it is more important to concentrate on contrast in the picture than on added brightness. By 'contrast', Dr. Goldmark refers to the relative difference between the whitest white and blackest black in a picture. According to Dr. Goldmark, a ratio of at least 30 to 1 contrast is needed if a satisfactory picture is to be produced."

Throughout the hearing, as has been pointed out above, the industry engineers used existing apparatus to limit the description of the field sequential system in 1947. Since it accepted this criterion of judgment on all other points, the Commission had an opportunity to find positively that the highlight brightness of the field sequential color receiver requires only a fraction of the highlight brightness of black and white receivers. Filters in the disc consume 90% of the ambient light in the room and upon reflection from the face of the tube again, the disc filtered another 90% of the remaining ambient brightness of the room, leaving only 1% effective on the field sequential color picture. On this record the apparatus gave the field sequential color system advantages over the black and white system, and the Commission disregarded it.

Dr. Goldmark explained the difference between the use of a disc in field sequential color and the absence of a disc in black and white pictures assuming an ambient illumination in the room of 20 footlamberts. In viewing the color picture at 20 footlamberts room illumination, 90% of the ambient light was filtered by the disc when it reached the face of the tube and another 90% was filtered again by the disc when it was reflected from the face of the tube. Thus the effective ambient room light upon the color picture was 1% of 20 footlamberts, or .2 footlamberts. Therefore, to maintain a 30 to 1 contrast ratio in the color picture, a receiver highlight brightness of only about 6 footlamberts was required. However, with a black and white television set where the room illumination is 20 footlamberts, ¾ of the ambient illumination, or 15 footlamberts, was reflected from the face of the tube. Since the darkest black in a television picture can be no darker than the reflected ambient illumination in the room, which in this case was 15 footlamberts, in order to maintain a 30 to 1 contrast ratio, it would be necessary to have a highlight brightness of approximately 450 footlamberts—30 times 15 footlamberts. [fol. 237] Thus Dr. Goldmark said:

> "Hence, if you want to get the same enjoyment, the same contrast, as in this photograph, namely, thirty to one, you should have the brightest portion in the picture thirty times as bright as the reflected light from the screen.
>
> "Now, I said fifteen footlamberts were reflected;

that you get, whether there is light on the screen or not. You multiply that by thirty, and you get 450 footlamberts highlight brightness only where the black-and-white receiver is run at the brightness where the highlights are 450 footlamberts high will it give the same satisfaction as a color picture run at twenty footlamberts." (Docket 7896, p. 326)

Accordingly, had the Commission followed the criterion that the industry used and that it used in its decision, the 15 foot lamberts of highlight brightness for the CBS picture as demonstrated with a contrast of 30 to 1 should have satisfied the Commission as to adequate brightness of the field sequential system in 1947. This the Commission refused to do. This amounted to failure on the part of the Commission to recognize one of the great advantages of the field sequential color system's use of the disc receiver.

[fol. 238] Flicker

Heretofore we have shown that the field sequential system potentially can develop all the light that is necessary for an adequate color system. In the 1946-47 hearing the industry said in effect that even if the field sequential system can generate sufficient light for an adequate color system, the color frame rate (24 color pictures per second; 48 primary color frames) places too low a ceiling on the objectionable flicker threshold for an adequate color system. This it was stated that the maximum brightness without flicker which the field sequential system could achieve was about 23 foot lamberts.

The Commission's position on the objectionable flicker threshold for the field sequential system is stated in the 1947 decision as follows:

"In summary, the Commission is unable to conclude from the evidence that the brightness of the Columbia picture is adequate for home use under normal circumstances or that it can achieve such brightness without encountering objectionable flicker. In the absence of more convincing evidence on the point, the Commission is of the opinion that on the point of brightness and flicker alone, the risk of approving the Columbia standards at this time is that color television might

be forced to limp along with a picture that is not sufficiently bright for general home use or is subject to objectionable flicker." (11 FCC 1531)

The Commission in its foregoing conclusion accepted the industry's view that the threshold of objectionable flicker was at a much lower level than the effective highlight brightness of existing black and white receivers. They claimed that in the foreseeable future the black and white standards provided ample opportunity for 100 footlambert highlight brightness without objectionable flicker. In accepting the doctrine of the industry, the Commission used against CBS that portion of its testimony which confirmed the industry position. It said:

"However, even if we use the testimony of Columbia's own witnesses, flicker becomes apparent (i.e., 'threshold flicker') at 23-foot lamberts and begins to be objectionable (i.e., maximum tolerable flicker) at 52-foot lamberts. As has already been pointed out, on the basis of the evidence before the Commission, there is no real assurance that greater brightness is necessary for normal home viewing conditions." (11 FCC 1529)

There was no valid reason for the industry to misjudge the field sequential color system employing 24 color picture frames per second or 48 primary color frames per second, because as early as 1940 these same industry witnesses had appraised a black and white television system of 24 frames or 48 fields and found it satisfactory for a commercial television service so far as effective highlight brightness of pictures was limited by flicker threshold. To demonstrate that flicker was not a problem with a 24 frame system, it is [fol. 239] necessary only to examine the testimony of two outstanding electronic engineers during the 1940 television hearing. Thus, David B. Smith testified for Philco in 1940 as follows:

"The Witness: The Du Mont proposal is being considered by the RMA. We have asked through the RMA that certain additional tests be made. We don't have complete information on that subject. We do have an open mind on it. We want to point this out,

that it is perfectly possible and has been demonstrated time and time again, both in the moving picture industry and in the British television practice, to cut the number of frames down to 24 frames, that is, a field frequency of 48. Now, that change from 60 to 48 does not require—In other words, you are still keeping within the retentivity of the eye which determines whether or not you have flicker." (Docket 5806, pp. 276-7)

And Dr. Engstrom testified as follows:

"Q. How many frames per second do you need to have to get a picture without a flicker?

"A. For apparatus that is practical, I should say that you should have at least 24 frames per second and a field frequency of 48 per second. Now, at a frame frequency of 24 per second and a field frequency of 48 per second, and considering the fact that 60-cycle power is the accepted and usual power supply frequency in this country, the problem placed on the receiver is a very difficult one, because things that we know of as hum, as a result from those power supplies, show up on the picture and have a very detrimental effect. Now, receivers could be built for 24 frames and 48 fields but they would be more expensive and they would not perform as well as receivers built for 30 frames and 60 cycles, and the reason for that is that there must be an energy relationship between the frame frequency and the power supply frequency." (Docket 5806, pp. 937-8)

It is to be noted that in rejecting the 24 frame black and white system, Dr. Engstrom relied solely on the matter of power supply, which we now know was never a real engineering problem.[9] He did not find any fault at all with the 24 frame system so far as flicker is concerned.

By the time the 1946 hearings on color had started, the [fol. 240] industry and the Commission had forgotten the

[9] In building receivers the industry thought at the time that a television system employing 60 fields per second could be more easily manufactured than a 48 field system in view of the 60 cycle power supply.

industry's testimony in 1941 on the adequacy of pictures unlimited by flicker in a 24 frame rate system.

It will be noted that the foregoing statements made in 1940 were based upon the calculated maximum highlight brightness that the system of black and white would generate at the 24 frame rate without reaching the point of objectionable flicker. We have also seen, as discussed heretofore under brightness and contrast, that the industry used the apparatus demonstrated in 1947 to establish that the CBS system could not achieve adequate brightness. With reference to the maximum brightness of the CBS system as demonstrated, they had said that 90% of the tube light was filtered out by the disc; the Commission accepted this apparatus reasoning to establish the maximum brightness of the *system*.

But when they approached the subject of maximum highlight brightness of field sequential color pictures for the purpose of discussing flicker, they found it served their purpose to talk about it theoretically without reference to existing apparatus—disc receivers. Specifically, they now wished to judge the field sequential system potential highlight brightness on the same theoretical basis that they were judging the black and white system. In other words, they wanted to use the brightness potential of the black and white system to kill off the field sequential system on the grounds of its reported low flicker threshold. On this basis, David B. Smith said that the field sequential system could never provide satisfactory brightness below the level at which flicker would become objectionable. He said:

> "In our view, it would be a serious mistake to establish a brightness ceiling for color television lower than that of the present black and white service, which would be the case if the proposed standards are adopted." (Docket 7896, p. 519)

Dr. Goldsmith also treated the field sequential color system demonstrated with discs as if the discs with their contrast capabilities were not present. He compared the brightness that would be needed for a 60 field system with a 48 field system on this basis, and concluded that flicker would be objectionable in the field sequential system at 24 footlamberts, thus making unuseable brightnesses above

24 footlamberts which he claimed were necessary for an adequate commercial color system. He said:

> "Color receivers providing 20 footlamberts have been demonstrated.
>
> "It is our opinion, however, that brightnesses far higher than 20 footlamberts are necessary for satisfactory color program reception. A tube, such as the Trichromoscope, can produce brightnesses of several hundred foot lamberts. Very objectionable color flicker will occur with brightnesses of this magnitude. Accordingly the color repetition rate of 48 per second is not adequate for a color television system. We suggest [fol. 241] that a repetition rate of 60 per second will probably be satisfactory, particularly if a simultaneous method of transmission is employed." (Docket 7896, pp. 1450-1)

RCA buttressed the Philco and Du Mont positions that highlight brightnesses much higher than that demonstrated by CBS were on the immediate horizon in 1946-47. Thus, George L. Beers testified that for a 10-inch receiver a normal brightness is 60 footlamberts.[10] He said:

> "In the case of the 10-inch receiver the highlight brightness in footlamberts which we consider to be normal for that receiver is 60. I believe reference was made to a receiver which gave a highlight brightness of only 20 footlamberts.
>
> "The only comment I could make there is that it is quite possible the receiver is not in proper adjustment. There is an ion trap employed in that receiver which must be properly adjusted in order to obtain maximum brightness, and although it happens in very rare instances it is, of course, possible that the receiver might be defective." (Docket 7896, p. 766)

At the demonstration by CBS of its field sequential color receivers in New York in 1947, Du Mont had black and white direct-view receivers which could produce 750 footlamberts

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[10] As has been indicated above, John V. L. Hogan's study of the highlight brightness of existing black and white receivers indicates that even today the average highlight brightness is but 17 footlamberts.

of highlight brightness, and Philco had a projection receiver that could produce pictures of 35 footlamberts highlight brightness. However, as the very record indicates, the effective highlight brightness without objectionable flicker was not 750 footlamberts but was about 280 footlamberts. This is established by Commissioner Jett's observations that at 280 footlamberts he personally got flicker. Commissioner Jett's observations are as follows:

> "Commissioner Jett: I would like them to reduce the highlight brightness of the white picture, the black and white picture, to about 280 footlamberts, to see whether or not the flicker had disappeared.
>
> "I personally get a flicker at that high brightness. I don't know whether anyone else does or not." (Docket 7896, p. 1066)

[fol. 242] All of this presentation by the industry, both of black and white receivers with circuits built in them which would produce highlight brightnesses much higher than those on the commercial market both in 1947 and 1950, and the testimony that in the immediate foreseeable future black and white commercial television receivers would create useful highlight brightness of 100 footlamberts, could only have been intended to mislead the Commission into believing that the field sequential pictures could either not achieve a highlight brightness of high magnitude or that if they did they would pass the point of objectionable flicker.

In summary, when the industry considered the problem of flicker threshold for the field sequential system, it pretended to discuss the maximum potential highlight brightness that could be achieved with a 48 color frame rate on a theoretical basis. However, it was misleading in its representations as to the maximum potential highlight brightness of the field sequential system since its premises for objectional flicker threshold were based upon fast decay phosphors in use at the time on black and white television apparatus. The coefficient of decay of these phosphors is not 1/30th of a second (the frame rate of black and white television) nor 1/60th of a second (the field repetition rate of black and white television). As a matter of fact the phosphors decay so fast after impingement of the electron beam upon them that they are readily used by the field sequential color system at the rate of 144 fiel-s per second without leaving any smear upon the picture utilizing the color discs.

What the industry refused to take into account was the use of long persistence phosphors. Dr. Goldmark, however, testified with reference to raising the highlight brightness potential of field sequential color without flicker utilizing long persistence phosphors. He said:

> "If pictures brigh-er than 25 footlamberts, which is the upper limit of presently available equipment, are desired, merely increasing the color frame frequency is not the answer. The solution will lie in electronic color tubes on which many organizations, including ourserves are now working.
>
> "When these tubes are fully developed, they will automatically carry with them additional protection against flicker in the form of long peristence phosphors which, as I pointed out in December, would raise the flicker threshold illumination to 110 footlamberts." (Docket 7896, pp. 1600-1)

The Commission did not give weight enough to Dr. Goldmark's testimony to make a finding on this point, even though Dr. Goldmark referred to the work done by Dr. Engstrom in support of his thesis. Dr. Goldmark quoted the following from Dr. Engstrom's study:

> [fol. 243] "Mr. Plotkin: Have any tests been conducted to show the effect that you have just described; towit, that the longer persistent phosphors mean a bettering of the flicker situation.
>
> "The Witness: I am coming to that later. Tests have been conducted in this direction by Mr. Engstrom in 1935.
>
> "I would like to refer to Exhibit 91—CBS 125—which illustrates why the flicker threshold will be increased by such a large factor, namely, 5." (Docket 7896, p. 1601)

The Commission timidly adverted to Dr. Goldmark's testimony concerning the use of long persistence phosphors to raise the flicker threshold of the field sequential system. But more important still, the Commission decision did not accept the evidence that the flicker threshold was not a limiting factor on brightness for the field sequential system and could be solved by long persistence phosphors, then

called slow decay phosphors. The Commission merely recited the claims of CBS as follows:

> "Another possible solution was suggested by Dr. Goldmark. He testified that it was possible to increase brightness without changing the frame rate and still avoid flicker. This could be done, he stated, by employing tubes with a slow decay phosphor. Dr. Goldmark admitted that such tubes have not yet been developed. Moreover, R. C. A. testified that it had experimented with such tubes and found them to be very complicated. Witness for Du Mont testified that that company had also conducted experiments with tubes having slow decay phosphor but found them objectionable. Apparently such tubes resulted in objectionable trails being left on the face of the tube. It is not possible to resolve this dispute until tubes of the type described by Dr. Goldmark are in fact developed and are sufficiently field tested so that it can be stated with assurance that they will work satisfactorily." (11 FCC 1530)

In summary, when the field sequential system uses black and white set receivers with a disc mounted in front, the phosphors on the face of the black and white receiver have decaying rates of 1/144th or less of a second because they do not produce smear on the color picture. Therefore, the flicker threshold of 23 footlamberts for the disc receiver as asserted by the industry is probably correct. On the other hand, when black and white receivers with 1/144th of a second decay rate phosphors are not used, and a triphorsphor tube of the Lorenzen, RCA or Lawrence type is employed, phosphors can be utilized which would have a decay coefficient as long as 1/24th of a second (the color picture frame rate of the field sequential system). This is amply proved by the 1950 record, as will be discussed hereinafter.

It was necessary for the 1947 Commission to have made this distinction in the generalized testimony of the industry [fol. 244] witnesses who are attempting to lick the field sequential system by disregarding the science of phosphor decay. In failing to make a proper engineering appraisal of the science of phosphor decay, and in failing to recognize

that the industry was shifting signals in its testimony, the Commission came to the erroneous conclusion that:

> "In the absence of more convincing evidence on the point, the Commission is of the opinion that on the point of brightness and flicker alone, the risk of approving the Columbia standards at this time is that color television might be forced to limp along with a picture that is not sufficiently bright for general home use or is subject to objectionable flicker." (11 FCC 1531)

To find how wrong the industry was in 1947 concerning the effective highlight brightness potential of the field sequential system in relation to objectionable flicker threshold, we need only refer to the present hearing record wherein the field sequential system was demonstrated on an all electronic receiver with highlight brightness of 600 footlamberts on the face of the tube. The long persistence phosphors utilized on the CBS tube have the same coefficient of decay as the RCA tri-phosphor tube.

The field sequential system when it is viewed on a direct-view electronic receiver simulates simultaneous transmission of the three primary colors as reproduced on the face of the tri-phosphor tube by reason of the characteristics of the long persistence phosphor. There is no evidence in the record that anyone witnessing the demonstration in New York saw smear, although Mr. Fink [11] and Dr. Gold-

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[11] Mr. Fink's testimony of course was given before his recent trip to Europe. In a report of the CCIR dated June 30, 1950, and based on actual observations he made in Britain of a demonstration of black and white television of 50 fields per second, he says:

> "Studies of Flicker
>
> "Tests conducted at the RCA Laboratories in Harrison, using members of the study group as observers, revealed that images scanned at 60 fields per second could be viewed at highlight brightness from 50 to 8 times greater than when scanned at 50 fields, for the same visibility of flicker. This fact, which had been advanced by the U. S. delegation at Zurich in support of the 60-field American standard, impressed many of the delegates as justifying adoption of the 60-field

smith predicted that smear would appear. Commenting on this testimony, Dr. Goldmark said:

> "My earlier testimony that there is no practical ceiling on brightness of CBS pictures for the future was demonstrated on April 26, 1950 in New York with the use of longer persistence phosphors as used in the CBS all-electronic projection receiver, and also in the [fol. 245] RCA tri-color tube. The use of such phosphors with the CBS system will permit pictures free from flicker well over 100 foot lamberts.
>
> "The green picture employing a long persistence phosphor shown in the tube in New York and shown to the Commission on April 26 was 600 foot lamberts bright.
>
> "Dr. Goldsmith in his testimony the other day, and Mr. Fink earlier, ignored that fact that there are phosphors such a willimite. As a matter of fact, willimite was one of the first phosphors ever used in television tubes, and the green phosphor was used in the earliest RCA field test receivers.
>
> "This willimite is also known as zinc orthosilicate, which has such a characteristic that it alone permits

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rate. But a demonstration of flicker reduction using a long-persistence black-and-white silicate phosphor, at the Philips laboratories in Eindhoven, had the opposite effect, with the result that all the conferees except the U. S. delegation voted for the 50-field rate.

. . .

"Using this silicate phosphor, the highlight brightness for tolerable flicker was increased about 7 times over that permissable with a short-decay sulphide white-light prosphor, when both operate at 50 fields. The increase in brightness in going from 50 to 60 fields, with short-decay phosphors, is about 6 times. Accordingly, the long-decay phosphor provides an improvement, at 50 fields, about equal to that in increasing the field rate from 50 to 60 per second."

It should be noted that the CBS system has a primary color field rate of 48 which, because of its close approximation to 50 fields per second, makes Mr. Fink's observations equally pertinent to the field sequential color system.

raising the flicker threshold brightness by an appreciable factor, namely five times. I say if the other two phosphors didn't even have long persistence, just if the green were long persistence, it would raise it approximately five times, and at the same time produces no effect of smear whatsoever, in view of the fact that its luminosity after excitation decays to a negligible value within 1/24 of second, which is the picture period of the CBS system.

[fol. 246] "Drs Goldsmith and Mr. Fink talked about smears and trails and were ignorant of the characteristic of this type of phosphor.

"Now this willimite phosphor is used in the RCA tri-color tube, and was used in the CBS all-electronic receiver in the fall of 1948 when we demonstrated that receiver to the Commission and, of course, on April 26, 1950." (Tr. 11226-7)

The testimony of Dr. Goldsmith that the field sequential system could not reach a highlight capacity of 100 foot lamberts without flicker is also discredited; Dr. Goldsmith had stated:

> "And if you go up to brightnesses of the order of that currently used in black and white television of 100 foot lamberts, then the flicker would be very definitely objectionable." (Tr. 5352)

JTAC, which claimed that it was basing its report solely on system potentialities, did not fully recognize long persistence phosphors as being within the system capabilities of the field sequential system. It did, however, refer to them in a footnote in connection with the elimination of color breakup. It stated: "Longer persistence phosphors, as used in the all-electronic receiver, have almost eliminated color breakup." This table shows the utter confusion of JTAC in mixing system with apparatus. As we have pointed out, it presumed a color disc was necessary in that part of the report dealing with how you get color in the CBS system. However, when it discussed color breakup it referred to both all-electronic receivers and longer persistent phosphors. But lo and behold! when it discusses flicker it fails to mention the effect of longer persistent phosphors on raising the flicker threshold and effective highlight brightness of the CBS system.

The attitude of the industry toward the question of flicker

in connection with the field sequential system is further illustrated by the fact that at the CBS demonstrations in October 1949, many representatives of the industry testified that they saw flicker in the CBS pictures. Since the CBS highlight brightness during the October 1949 demonstration was about 20 foot lamberts, it was most unlikely for anyone to have seen flicker in the pictures since the flicker threshold for the type of receiver demonstrated was in the neighborhood of 23 to 24 foot lamberts. While it would be possible for some people at a viewing distance of 4 to 1 to see flicker at a highlight brightness of about 20 it is almost completely impossible for anyone to see flicker on a 10-inch receiver at that brightness when the viewing distance is more in the order of 15 to 1 if not more; and that is the distance at which some of these observers stood who claim they saw flicker on the CBS receiver. It is significant that those who testified that they saw flicker under these conditions were all representatives of the DuMont and Philco companies who had made the theoretical predictions that flicker would be present long before the maximum effective highlight brightness of the present day receivers was reached.

[fol. 247] Thus, it will be seen that in 1947 and 1950 the record established that maximum effective highlight brightnesses of much smaller magnitude than present day black and white receivers may be utilized to give an excellant color picture with a field sequential system using a filter disc in front of the black and white kinescope. This true because a contrast ratio of 30 to 1 is maintained. Of almost 12,000 people who have viewed the color disc picture, very, very few have found it to be unsatisfactory, and a very small percentage found any defects.[12] Further, the potential

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[12] On March 27, 1950, Dr. W. R. G. Baker said in an address:

"On the other hand, the real figure of merit to be attached to any system of standards cannot be accurately measured by engineering considerations. The real measure which is not subject to controversy is the acceptance by the public of the system of black and white television made possible through the application of a specific set of system standards. That is, the market place is the final judge of acceptibility." (Dept. of State Publication Serial #686, Document #9)

maximum effective highlight brightness without objectionable flicker has been demonstrated on the record with the all-electronic tube on a projection receiver at highlight brightnesses of 600 footlamberts on the face of the tube.

[fol. 248] Channel Width

In the 1947 decision the Commission made the following statement with reference to bandwidth required by the field sequential system:

> "Secondly, further experimentation should be conducted along the line of finding methods of transmitting color television over narrower channels. Under the Columbia proposals, each television channel would be 16 megacycles wide. That means that the band 480 to 920 megacycles would accommodate but 27 channels. It was the Commission's hope in allocating the band 480 to 920 megacycles for television that in this band it would be possible to provide for a truly nationwide competitive television system. The evidence before the Commission shows that 27 channels may not ultimately be enough to provide for a truly nationwide competitive television system. Every effort must, therefore, be made to narrow the band width required for color television. It should be emphasized that narrowing the band width should not be at the expense of picture brightness, picture detail, color fidelity, or other features of television performance. The objective should be a narrower band — it would be possible to provide for a truly nationwide competitive performance." (11 FCC 1535)

Whatever may have been the motives of the parties in not proposing to the Commission 6 mc field sequential color, the Commission itself should have remembered that the work on the field sequential system in 1940-42 was in the 6 mc channel. The recommendations of the NTSC, subsequently incorporated into the Commission's first Standards of Good Engineering for black and white television, proposed field testing of the field sequential color system in 6 mc bands with 375 lines, 120 fields. While it is true that some more work would have been necessary in 1947 to put the field sequential system back into a 6 mc bandwidth, the testimony throughout the proceeding and the Commission's

decision apparently was confined solely to 16 mc with reference to the field sequential system.

Since it was generally known in the industry that field sequential color could be achieved in 6 mc, the Commission was unsound in turning down field sequential color on the specific ground of bandwith without further consideration of the possibilities of 6 mc color.

[fol. 249] Color Fidelity

No one has ever seriously contended that the most important aspect of a color system, the *color fidelity*, does not meet up to the highest standards in the field sequential system. Dr. Geer on the record testified that we cannot expect much better quality from a color system. (Tr.3923)

Dr. Judd testified as to the reliability of the CBS field sequential system. He said:

> "I would say that it is my impression that the color rendition by the CBS system has been uniformly good. The color pictures shown by the RCA and the CTI systems have been occasionally good and occasionally bad . . . I would say the CBS pictures were uniformly better, but that the margin which they had did not consist essentially of color fidelity. It consisted in clear pictures, adequate brightness, and freedom from any misregistration." (Tr. 9313, 9315)

With reference to the CBS system, he was so satisfied with the quality of the CBS picture that he stated he would like to buy a color receiver if CBS were adopted, even though he did not then have a black and white receiver. (Tr. 3757)

In addition to the testimony of experts such as Dr. Geer and Dr. Judd, we have, of course, the overwhelming approval of the public which viewed the field sequential color pictures. Especially significant is the fact that doctors who would be especially critical of color fidelity rated the CBS system very favorably. So far as the general public is concerned, in the first Walker Building tests over 70% rated the trueness to life of the color pictures as excellent or very good, 21% rated it good, 6.4% rated it only fair and .06% as poor. In the second Walker Building survey the results were even more favorable.

About the only evidence to the contrary are the same witnesses who have for ten years seen ghosts in the closet of the field sequential system and color television in general.

[fol. 250] Compatibility

We have on the scales two weights. On the one hand we have the field sequential system, presently adequate and with full potential for improvement. On the other balance we have the prospect of compatible color systems. These color systems presently are not yet even completely off the drawing board. RCA and CTI still do not know what will be in their field pickup camera equipment. Can we then gamble color for the American people in the next generation against the prospect of paper systems being developed into sound color systems?

No one has taken the position that if there is only one way to get color, via an incompatible system, we should stick to black and white. RCA and the industry's whole position on compatibility is based on the assumption that engineers may some day provide us with an adequate but yet compatible system. But to argue that compatibility is more important than color, when there is slight prospect of an adequate compatible color system, is to argue that existing black and white is better than non-compatible color when that is the only system which so far as we can see today will provide color for the American people immediately. But compatibility is not more important than color itself. Such was the testimony of an inventor in this field, Dr. Geer. (Tr. 3933) And such was the testimony of Dr. Engstrom in 1946: "My personal point of view is that compatibility is second to adequacy of performance, that performance must be met first." (Docket 7896, p. 1355) Exactly to the same effect was David B. Smith in 1946: "Well, speaking for myself, I think it [compatibility] plays quite an important part. It seems to me the first requirement is that the system work, but assuming you had two systems, both of which worked, then I would say the compatibility would be a very important factor in deciding which one you would use." (Docket 7896, p. 1388)

The Commission itself rejected the notion that color standards would be tied down by the concept of compatibility. It said:

> "This so-called principle of compatibility, it is urged, will encourage manufacturers of black and white equipment to proceed at full pace, will enable the public to buy receivers with confidence that they will not be rendered obsolete, and will not impede the development

of color television. The Commission is of the opinion that compatibility is an element to be considered, but that of greater importance, if a choice must be made, is the development of the best possible system, employing the narrowest possible band width, and which makes possible receivers capable of good performance at a reasonable price." (11 FCC 1535)

[fol. 251] Equipments

We have today but one possible color system that works. The quicker we finally adopt that system, the quicker the industry will develop the commercial equipments to get color to the American people.

The Commission has now had ten years experience with the development of apparatus by the industry for color television. So long as the Commission refuses to set standards for color television, just so long can we expect that the equipments which will make color television a reality for the American people will not be produced. As a matter of fact, the history has been replete with evidence that the radio manufacturing industry individually have not produced equipments unless they are applicable to an entire color system of their own. In other words, the only people who have made color equipment are proponents of specific systems. Those who have been proponents of systems that have competed with the field sequential color, once having been able to convince the Commission that there was promise in their system that might be developed later, have not worked upon the commercial development of the equipments that would make that system practical. The history of RCA's failure to develop commercial equipments for its simultaneous and dot sequential systems will be discussed more fully in subsequent sections.

On the other hand, the apparatus for field sequential color has been found by experience to be thoroughly practical. The field sequential system as proposed by CBS has utilized equipment in the medical demonstrations where the conditions of pickup were as adverse as those in remote pickup of regular commercial broadcasting. CBS medical studio equipment (the same utilized in the color field testing) has operated in many areas all over the United States and has shown color pictures to 100,000 doctors without a single

breakdown. Moreover, 16 medical conventions will use this field sequential system apparatus in the coming year.

The practicality of the field sequential system's apparatus is further demonstrated by the fact that that system is the only color system which is presently feasible for industrial purposes. Thus DuMont, which a short time ago announced an industrial color system, has incorporated almost in toto the color apparatus used by CBS. He testified that he chose the field sequential system for his own industrial color system because it was the fastest way to get a color industrial system.

What will be the apparatus situation if the Commission adopts standards for the field sequential system immediately? In the first place, color television, up through a 12-inch picture, would be available to the American public immediately. Existing black and white set owners would have the opportunity to convert these black and white sets so that they could receive pictures in color. Those potential set owners and existing set owners who did not desire to see field sequential color in color will be in a position to view these transmissions in black and white on receivers of any size that the industry may build. But more important than anything else is the fact that once standards have [fol. 252] been set, the television industry will then have the stimulus to develop one or more types of direct-view electronic tubes. And in addition, once standards are set, persons such as Dr. Lawrence, not directly connected with the radio or television industry, will have an immediate incentive to work on tubes that could be used in field sequential color.

Only if the Commission adopts standards for color now will American industry produce equipments to give the American public the full developed color system it deserves at the earliest date possible.

[fol. 253] II

In December 1946 hearings began on the petition of CBS to open up the UHF for its wide band field sequential color system. As in this (1949-50) proceeding, nearly the whole industry made known on the record its opinion that they were opposed to the adoption of the CBS system. As an alternative to the field sequential system there was suggested by RCA the simultaneous system. We know now

that this system could not possibly have been made the basis for a sound color service because it couldn't pass over the first hurdle of multipath and other propagation problems. On the record of this proceeding, it has been made clear that if the Commission had adopted the simultaneous system we could not have, today or ever, a color service. Thus, Mr. Plotkin asked Dr. DuMont:

> "Q. Had the Commission in 1947 adopted a simultaneous system of color transmissions, do you think there would be color today?
>
> "A. I rather doubt it." (Tr. pp. 9400-9401)

RCA admitted the complete failure of the simultaneous system.

> "Commissioner Jones: Well, I assume that you conducted field tests with reference to the simultaneous system.
>
> "The Witness: We conducted numerous tests in the laboratory but never got radio transmission because of our problems with regard to UHF propagation." (Engstrom, Tr. 2773)

In other words, despite all the claims by the industry of the great superiority of the simultaneous system over the field sequential system and despite the fact that RCA tried to broadcast signals of the simultaneous system, no radio transmission was ever obtained which produced satisfactory color pictures.

In view of the history of the simultaneous system, it becomes highly pertinent today to examine the 1946 testimony of those who now support the dot sequential system. RCA testified at great length concerning its then newly conceived simultaneous system. It is very significant that this testimony in its total effect did not merely lay before the Commission the possibility of a color system; rather, RCA expressly represented to the Commission that its simultaneous system *would be* a sound color system. [fol. 254] Dr. Jolliffe testified:

> "Further developments and improvements in television must and will be made. One of these developments will be a color television system which can become an integral part of television service. RCA has

developed the basic elements of an electronic simultaneous color television system which can be introduced, when it is ready in the future, without obsoleting the present excellent electronic monochrome system." (Docket 7896, p. 646)

RCA, of course, recognized that its system was then in the developmental stage and not yet ready for standardization. Dr. Jolliffe stated, however:

"The basic principles are established beyond question, although the engineering details are yet to be worked out. This will require some time, as Mr. Kell will explain, but the end result will be an excellent and practical system introduced without penalty to the existing service and without jeopardy to the investment of public and broadcasters in black-and-white television." (Docket 7896, p. 664)

Considering the fact that there was no broadcast experience or field tests to prove the point for RCA, Commissioner Jett secured as a substitute for such experience the following from Dr. Jolliffe when he asked:

"You could guarantee that?";

and Dr. Jolliffe replied,

"Yes, sir." (Docket 7896, p. 664)

Thus, we have here a guarantee by the head of the RCA Laboratories that the simultaneous system was certain to be developed into a satisfactory color system.

Dr. Kell testified for RCA as follows:

"Work on this simultaneous system using modern tubes and techniques has been carried to the point where all the basic factors have been studied, and the ultimate success of the system seems assured. From the work that we have done, we are convinced that the simultaneous system is basically superior to the sequential system of color television transmission . . . ." Docket 7896, p. 686)

[fol. 255] Thus, it is clear that in 1946 RCA represented without equivocation to the Commission that the simul-

taneous system was the best system by which the American public could get color television, that all its basic principles had been tested and the Commission could postpone the adoption of a national color television system until commercial equipment were developed for its utilization.

The present announcement of RCA of its dot sequential system as a reincarnation of the simultaneous system was launched on the proposition that its system was fully "developed". They tacitly represented to the Commission that their system was nearly ready for adoption as a broadcast service. Then at the hearing Dr. Engstrom testified:

> "Based first upon the principles of simultaneous color television which provide high performance and second upon the band saving features which still provide this high performance with a 6-mc channel, *we have* in the RCA color system the course that color television should continue to take to reach realization as a broadcast service. Our field tests, now beginning, will provide for us, the Commission and the radio industry the extensive data and the assurance through experience needed to crystallize the service. We shall press forward with the field tests to obtain this information as soon as possible so as to permit transition to a regular color television service. We welcome others to join in the observations and tests." (Tr. 2745-6) (Emphasis supplied)

Upon cross-examination, however, Dr. Engstrom hedged and admitted that the system was far behind RCA's representations to the Commission. Exactly as was the case in 1946, RCA now stated that only the fundamentals of its system -as been allegedly tested:

> "By Mr. Chapin:
>
> "Q. You are acquainted with the release, 'Comments of Radio Corporation of America', dated August 25, 1949?
>
> "A. Yes, I am.
>
> "The Witness: I wonder, Mr. Chairman, if it might not be better if I finished reading.
>
> "The Chairman: I think we will have the question.

"By Mr. Chapin:

"Q. I believe this was signed by C. B. Jolliffe for Radio Corporation of America?

[fol. 256] "A. That is correct.

"Q. The second paragraph of that document states:

'RCA has developed a new color television system which does not require any changes in present transmissions standards.'

How do you interpret the phrase 'has developed?' What does that mean to you?

"A. It means that we have conceived, analyzed, put together a system *which operates.*

"Q. As of that date you were entirely satisfied that you had developed a new color television system?

"A. That is right, and that we have tested it as to fundamentals, because this was all done, as you understand from what we have said, in the laboratory." (Engstrom, Tr. 2715-6) (Emphasis supplied)

It would appear that the CBS demonstration of its more fully developed system by actual on-the-air broadcasts forced RCA to brazenly palm off a dot sequential system which in its first demonstration could not even qualify as a color system. In short, they made their demonstration on October 10, 1949, well knowing that their color and the other characteristics of the system would not live up in any way to the representation made to the Commission.

In the 1946 proceeding we find that Du Mont had offered very favorable testimony in behalf of the RCA simultaneous system. Du Mont stated:

"On page 13, last pararaph, and Page 14, first paragraph, of 'The Truth about Color Television' it states:

'All electronic color television systems are now under development by several companies. These systems may allow transmission of color television, not in color sequence by fields, but in color sequence by picture elements, or by picture lines, or possibly even by simultaneous transmission of all three colors.

'We therefore believe that it is far too early to consider standardizing on a scanning system which

is an outgrowth of obsolete mechanical color filters, when electronic developments in color may make it [fol. 257] possible in a few years to provide excellent color television free from this fatiguing flicker and color breakup.'

The last few words of the first paragraph and the last paragraph quoted, of course refer to the simultaneous system recently demonstrated. Although we are in favor of the simultaneous system as demonstrated, projection tubes were used which cannot compare with the results obtained when the picture is viewed directly off the cathode-ray tube." (Docket 7896, p. 1425, 1426)

Dr. Goldsmith stated:

"We have done considerable work on simultaneous color television systems, as already discussed by Dr. Du Mont and illustrated in his exhibits. I would like to re-emphasize that a simultaneous color television system can be made to be compatible with the present commercial black and white standards. This point has been emphasized by a number of witnesses and I will not dwell upon it in detail. However, I feel strongly that they are on the right track.

"I feel that if the Commission feels in necessary to standardize some color system at the present time, it would be highly desirable to choose such a simultaneous system so that the inauguration of such a commercial system can follow smoothly from the present black and white television operations." (Docket 7896, p. 1468, 1469)

Dr. Goldsmith had a time table worked out, obviously on the basis of the simultaneous system. In it he agreed with the RMA conclusions. He stated:

"The proposed schedule for color television development, revised to date, is suggested as follows:

1) Expand black and white television service.
2) Develop color—two more years.
3) Set tentative color standards (one year).
4) Perform color field tests (one year).
5) Obtain FCC approval—one half year.

6) Provide color stations and receivers and establish full commercial service. (One year)

This indicates a period of five and a half years remaining before full commercial color television operation can be accomplished.

[fol. 258] "I might add that I was a party to the RMA deliberations on schedules and I agree 100 per cent with the findings. This is a recapitulation of the particular series of operations that we as a company might follow if we were going to go into this color business, and the schedule does not necessarily conflict with the RMA report. The RMA report is a sort of an industry composite plan to go into the color television business, and might move more rapidly in certain respects.

"Some of these things I have listed in sequential might operate to parallel and reduce it, but it is interesting to note that the five and a half years is not very far off from the ultimate commercial estimate of the RMA report.

"The final summary is about the same." (Docket 7896, pp. 1470, 1471)

Du Mont's position in the present proceeding with respect to the dot sequential system is somewhat unclear. At the beginning of the hearing befor the CBS system had been completely field tested, Du Mont in its written comments made a devastating attack on the RCA system as being so full of engineering defects that it would be impossible for it to materialize into a sound system. Later on in the hearing when it became obvious that the CBS system had at least a fair chance of standardization because of superior performance, the tenor of the Du Mont testimony changed from one of despair to one of hopefulness for the dot sequential system. His tesfimony was to the effect that he believed the problems in the dot sequential system could be worked out. He testified especially that such things as registration could be solved.

During the 1946 hearing Philco took a similar position. David B. Smith, testifying in behalf of Philco at the beginning of the hearing stated:

"However, we have not had an opportunity, nor do we believe that anyone else has as yet had sufficient

opportunity, to evaluate the requirements of the simultaneous system as compared with the sequential system from the receiver point of view, to determine at this time which one is preferable." (Docket 7896, p. 526)

However, by the end of the hearing, Philco and David B. Smith were convinced that the simultaneous system was the better of the two. Smith's testimony was as follows:

"In the third place, we do not believe that the sequential system is the most practical system of color television now available in the art. During this hearing demonstrations have been given of a 60-frame simultaneous system.

[fol. 259] "This system has none of the fundamental limitations of the proposed system. It will permit pictures as bright as those permitted by the present black and white standards and more than nine times brighter than the proposed standards.

"Moreover, it provides the most practical method of receiver construction to obtain such bright pictures."

* * * * * * *

"3. There is now available in the development stage a simultaneous system of color television which is clearly superior to the proposed sequential system in performance capabilities. This simultaneous system will provide the public with more television at less cost and will eleminate the problem of technical obsolescence, thus clearing the way for rapid expansion of the television industry. Development of the superior simultaneous system would be stopped if the proposed sequential standards are adopted." (Docket 7896, p. 1847, 1848, 1849)

Commissioner Hyde apparently had some question with respect to the reason for Smith's certainty with respect to the superiorty of the simultaneous system. The following appears in the record:

"Commissioner Hyde: Has anyone seen a demonstration of simultaneous television which had acceptable registration and acceptable brightness by which

to judge it as being superior to a demonstration which we have seen of a sequential system?

"The Witness: Well, I think that you should make your own judgment as to what you have actually seen.

"I will state to you, however, as an engineer that I am convinced, and I believe it would be agreed, that the cabilities of the simultaneous system are superior to those of the sequential system." (Docket 7896, p. 1851)

Philco's position in the current hearing has been somewhat similar to Du Mont's. It originally took the position that none of the color systems was ready. Later it argued that the dot sequential system is the one that shows the most promise.

It is almost something of a rude shock when one compares the unequivocal statements of RCA witnesses and others that the simultaneous system would become a sound system with the facts as we know them today. In evaluating this testimony we cannot, of course, be too critical merely because the engineers involved made a mistake with respect to the capabilities of the system. It must, however, be of great concern to the Commission that in giving this testimony these engineers did not merely stop with the assertion that this simultaneous system was a system that warranted further study. Rather the testimony in the 1946 hearing was:

[fol. 260] The simultaneous system could not fail of ultimate achievement and all that remained was the time to work out equipment devolopments. They categorically represented that development and field testing of equipments presented the sole time factor for a system superior to field sequential color. The significance of such testimony is almost obvious. It would tend to indicate to the Commission that there was in 1947 no risk in waiting for the future development of the simultaneous system rather than proceed with the adoption of the field sequential system.

The near recklessness of the testimony in the 1946 hearing becomes obvious when we become aware that the main difficulty with the simultaneous system propagation, especially the multipath propagation problem, was known to the whole industry. Although Dave Smith, testifying in behalf of the RTPB at the very start of the hearing, made clear that before the simultaneous system could be evaluated field tests were necessary with respect to the multi-

path problem (Docket 7896, p. 446), nevertheless, both he and the industry without such field tests made no reservations in recommending the simultaneous system in the final stages.

In view of Dr. Engstrom's testimony in this hearing, referred to above, that no successful radio broadcast was ever made with the simultaneous system solely because of this propagation problem, it is all the more startling to find that when the Chief Engineer of the Commission questioned Dr. George Beers in 1946 concerning the multipath problem, Dr. Beers brushed it aside as being equally applicable to the sequential and simultaneous systems. One significant thing stands out, however, in Dr. Beers' testimony on this point. He was not concerned that multipath affected the color fidelity of the simultaneous system while it did not affect in any way the color fidelity of the sequential system. This is but another indication of the very low weight which RCA, both in 1947 and in 1949 and 1950 gave to color fidelity. The following is the testimony:

"By Mr. Adair:

"Q. Mr. Beers, I wonder if you could give us any comments on the relative problems of multipath transmissions between the sequential and simultaneous systems?

"A. Well, I can give you some comments. They are only based on a limited analysis that I have given to the subject and on no experimentation at all. The effects will obviously be different.

"In the one case if you have a multipath effect, if it means an effect which results in a frequency discrimination, in other words, if you lose a certain band of frequencies in the spectrum that is being transmitted and received, in the case of a sequential system that result will be—assuming that that stays put with time—that result will be a loss in resolution in certain frequency portions of the picture, I mean in detail.

[fol. 261] "If certain frequencies are lost that will affect the resolution.

"In the case of a simultaneous system if a certain part of the frequency spectrum is lost it may change the color gradation in certain portions of the picture. It will have a different effect.

"But I would also like to say that if there are such effects and they are serious effects, which would not seem to be indicated by the testimony on propagation which has been given so far to the effect that with a high directive antenna you can minimize all these propagational vagaries, I think they would probably be equally serious in either instance. But if we don't have them we need not worry about them in any case." (Docket 7896, p. 770-771)

Solution of the propagation problem was a condition precedent to an engineer's ability to recommend the adoption of the simultaneous system to the Commission. History has proved that the propagation problem could not be solved and that for this reason the simultaneous system had to be thrown into the junk heap.[13] Yet more significant as far as final determination of this proceeding is concerned is the fact that the entire industry and its many eminent engineers who testified in 1946 and 1947 accepted the statements of Dr. Beers that what turned out to be an Achilles' heel of the simultaneous system was of minor consequence and really no technical problem at all.

Just as in 1947, RCA represented to the Commission that i-s system was sound even though its basic fundamentals had not been tested, so today RCA again represents to the Commission that its present system is sound although again its fundamentals are still but in a theoretical stage. Foremost among these theories of RCA is that with respect to the validity of the principle of mixed highs. RCA, of course, believes implicitly in the validity of its principle. In addition, on the record Donald Fink testified that the principle in general could be accepted. (Tr. p. 8091) On the other hand, both Dr. Baker of General Electric and David Smith of Philco either rejected or expressed grave doubt as to the validity of the principle. However, nobody other than the RCA testified that if the general principle were sound the appropriate cut-off for the application of the principle is 2 megacycles.[14]

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[13] It is recognized that portions of this junk heap were salvaged for black and white portions of the dot sequential system.

[14] As a matter of fact, Hazeltine in its demonstrations off the record to the Commission and in its written documents

[fol. 262] In view of this conflicting state of the record, it becomes of utmost importance to examine the testimony with respect to the principle of mixed highs more closely. This is especially true in view of the record and history with reference to multipath discussed heretofore.

At the outset, we must remember that the principle of mixed highs is not of recent origin. Dr. Kell in the 1946 hearing testified with respect to this problem. In his testimony he admitted that the use of mixed highs had the effect of reducing color fidelity. (Docket 7896, p. 737-741) In addition to the statement of the general mixed highs principle, Dr. Kell also testified with respect to the possibility of reducing the band width of the blue channel. (Docket 7896, p. 735-6)

During the demonstrations of the RCA system in 1947, questions were raised by Dr. Goldmark with respect to the soundness of the mixed highs principle, at least insofar as it used different bandwidths for the different colors. As a result of these question, Dr. Engstrom admitted that field tests were necessary and that they had not been completed. Dr. Engstrom said:

> "I do not think that the loss of detail in the high frequency end of the blue occurs- in any demensions, would bring about the effects that you have in mind.
>
> "On the other hand, I want again to emphasize that the simultaneous system may be operated with full band width in all of the channels, it may be operated with an attenuation of the blue band, and we at least believe that is proper; but we also appreciate that neither we nor anyone else has made all the tests that are necessary." (Docket 7896, p. 1163-4)

From the 1946-47 record, the ancestry of the mixed highs principle as presently conceived in the dot sequential sys-

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filed with the Commission indicated that if the principle of mixed highs is to be applied, it should not be applied with a 2 megacycle cut-off. Hazeltine conducted no field tests of live program material on a closed circuit nor did it field test its theorems by an actual on-the-air transmissions.

tem is made clear. Dr. Brown, during the current hearing, identified the mixed highs principle as follows:

"The principle of mixed highs, referred to previously, was described by RCA is Docket Nos. 7896 and 8976. It has been demonstrated that the mixed highs procedure is successful and satisfactory in a wide-band simultaneous system . . .

"I might review that for a moment. A few years ago Mr. Kell described, during the course of a hearing, the principle of mixed highs. I might try to outline it very briefly. That is simply this:

[fol. 263] "That the eye obtains a great deal of its color information in large areas, I should say not in small areas. That is, that the eye is not sensitive to color in fine detail. It sees in monochrome or essentially that. I think there could be a good deal of argument about just where you use the color and where you use mixed highs, but the result of a very large amount of work in the laboratories has led us to choose this figure of about 2 megacycles for our cutoff and our fringes and put all of our high frequencies together in what we call the mixed highs." (Tr. 2840-1)

Dr. Brown testified with respect to the possibility of reducing the band width of the blue channel in the dot sequential system. He stated that this, too, was based on theories explained during the 1946-47 hearing. He was questioned with respect to the basis for these theories:

"Commissioner Jones: Did you propose that publicly to anybody, that is, limiting the red and blue signals in band width as compared to the green signal which could be the full width?

"The Witness: Yes, to the Commission.

"Commissioner Jones: Did you have calculations on that basis?

"The Witness: Well, that business of mixed highs was done as a first of a series of physiological tests, external to the electrical circuits, in which many observations were made, and some observers to see that we, we were on the right track of seeing detail, monochromatic detail, on high frequencies, and once we had established a place where we thought that we

could cross over, take the mixed highs out and have color in this region and mixed highs here, we proceeded to design filters." (Tr. 7660-2)

Shortly after this testimony was given, he was again questioned with respect *of* the nature of the calculations that were made as the groundwork for the principle. He now stated that this was all the same as the work that was done in 1946.

"Commissioner Jones: What I am getting at is, there must have been calculations where you got right down to brass tacks on figuring out these formulae as to whether you would have a tenth of a megacycle for red, blue and green, or whether you would have something else, and the balance of it in black and white, and the mixed highs.

"The Witness: Well, but we had already decided back in 1946, that had nothing to do with this sampling principle, as such. That was in our simultaneous system. We had already made up our minds that we were going to take up to about 2 megacycles, and that we would have a really good color, and supply the fine detail with the mixed highs." (Brown, Tr. p. 7665)

[fol. 264] To sum up we find RCA relying exclusively on its 1946 experience for the validity of the mixed highs principle—a principle which is most basic to both the 1946-47 simultaneous and the 1949-50 dot sequential systems. Taking both records together, we find no description in detail of any tests that may have been conducted to establish the soundness of the principle. Taking both records together, we may only ascertain that the principle had been tested roughly in 1946 (Kell, Docket 7896, pp. 737-741) and that these tests apparently were *psychological* (Brown, Tr. 7660-7662). No tests apparently were made with respect to the dot sequential system's use of the mixed highs principle. So far as both records are concerned, we don't know the nature of any tests, how many subjects were used, whether the tests included radio transmission of subject matter, whether only the ability to see detail in color was tested or whether color fidelity and contrast effects were also studied. So for as the record in both 1946 and at present are concerned, the principle of mixed highs is a matter of complete theory, unsupported

by an- scientific data other than bare-faced statements by RCA witnesses and Donald Fink.

From the record it appears that the quality of the RCA dot sequential color picture is probably impaired because of the use of mixed highs. RCA, however, despite the absence in the record of detailed field tests or any other kind of adequate *psych*ological tests, refuses to recognize any doubt with respect to this principle. Upon questioning Dr. Brown, the following colloquy appears:

> "Q. In all your observations you have made on your mixed high system over-all, you don't feel that there is any problem at all of apparent loss in contrast when the mixed highs are used?
>
> "A. Mr. Chapin, I am, I think, as thoroughly convinced of the complete adequacy of the principle of mixed highs as, I think, anyone in the RCA organization." (Brown, Tr. p. 8502)

The question flares up and hits us in the face, "Why hasn't RCA in the period since the conception of the simultaneous system provided the Commission with an adequate basis for the validity of the principle of mixed highs?" Even assuming that it wished to kill color television by doing nothing from the period between the Commission's decision in 1947 and the institution of the current proceeding, it still has had a full year to conduct tests to establish the validity of the principle. So far as the record is concerned, would we be justified in assuming that some such tests have been conducted, since this principle goes to the heart of the system, and that the results of these tests have not been communicated to the Commission? Or can we assume that, as in the case of the multipath problem, RCA is really not concerned whether or not its color system will work so long as it offers the Commission another color "utopia" to prevent the adoption of the only sufficiently developed color system, the field sequential system? In either event, we are faced with the conclusion that so far as the principle [fol. 265] of mixed highs is concerned, there is something wrong in Denmark. Since the mixed highs principle was used in the 1946-47 hearings, un-field-tested, and again in the 1949-50 hearings un-field-tested, so far as the record is concerned on both occasions, we have no justification whatsoever for relying upon the prospective soundness or validity of the mixed highs principle.

In addition to problems of color fidelity in the RCA color system, caused by the use of the principle of mixed highs, the technique of color selection by dots also produces color degradation as a result of crosstalk. Crosstalk is caused by the signals from one color leaking over into the signals of another color. It is, on other words, the intermixture of dots of one color with dots of another. From the record it is clear that the problem of crosstalk is very important.

We have in fact on the record uncontroverted testimony that because of the problem of crosstalk, upon presentation of the keyboard pattern during the Laurel demonstration the RCA picture suffered from color contamination. This testimony, never rebutted by RCA, is as follows:

> "What further can happen colorwise is the cross-talk mentioned by RCA and which I was aware of earlier, due to the sample frequency relationship to the frequency transmitter.
>
> "It was stated by RCA that theoretically, I think, somewhere between .5 megacycles and 2 megacycles they can have cross-talk that causes mixed highs to be lost. We are below the limit of their mixed highs. And that cross-talk has shown up in their picture particularly on small color detail—not so small detail, rather.
>
> "You remember the Laurel demonstration with the keyboard—we will call it a keyboard chart. When that keyboard chart was vertical the alternate colors, the red, blue and green washed out, deteriorated in color. Not until it was large detail did they show up anywhere in some sort of fidelity, but the fidelity becomes tremendously bad. Only on the field sequential receivers did the colors maintain their purity to the end, or as far as they were resolved.
>
> "Now that is an effect of this color contamination I mentioned." (Goldmark, Tr. 9268-9269)

Despite the seriousness of crosstalk, when RCA first presented its case in the current proceeding, it brushed off this problem. Dr. Brown testified:

> "Likewise, the red and blue samples are each taken at points on the composite signal where no crosstalk is contributed from the other two color signals.
>
> [fol. 266] "The above statement concerning absence

of crosstalk holds good for all frequency components up to one-half the sampling frequency. For frequency components approaching the sampling frequency in order of magnitude, from a purely circuit aspect, crosstalk is present. However, the physiological characteristics of the eye which make possible the application of the mixed-highs principle apply equally well to the crosstalk of the higher-frequency components. Consequently, crosstalk in the fine detail is of no consequence." (Tr. 2875)

As the hearing progressed and the problem was aired, Dr. Brown gave more and more attention to the problem of crosstalk. In connection with his extensive presentation with respect to the theoretical nature of the sampling process in the dot sequential system, he now gave extensive treatment to the problem of crosstalk. Examination of this testimony indicates again that there was no concrete resolution but a minimization of the problem by the statement that it could be solved. We are here left again in the position of having to rely on unverified theory—theory that could have been proven by adequate field testing. Thus Dr. Brown stated:

"Later in the report we have shown circuit details of developments which completely eliminate this crosstalk."

Miss Hennock interrupted to ask:

"Well, do you have these developments now?"

Dr. Brown's reply:

"We are working on some of them; well, all of these that are in here, we are working on, and have done some work on, yes."

The full testimony on this point is as follows:

"The Witness: I have, for instance, just mentioned this color cross-talk at this point. Later in the report we have shown circuit details of developments which completely eliminate this cross-talk.

"Commissioner Hennock: Well, do you have those developments now?"

"The Witness: We are working on some of them; well, all of these that are in here, we are working on, and have done some work on, yes.

"Commissioner Hennock: Well, you have not perfected them?

"The Witness: Well, yes, I think so.

[fol. 267] "I might point out one as one example: This matter of color cross-talk, we have found that it is very difficult to evaluate by paper analysis what the cross-talk is, how serious it is to the eye.

"We have produced rather serious pictures with this quantity of 50 percent cross-talk, which mathematicians can uncover.

"In a paper which was passed out here at the hearing, but not offered as an exhibit by Philco, and published in "Electronics" Mr. Boothroyd chose 33⅓ percent cross-talk in our color system, and drops it there.

"I am sure that we have been conscious of that for a long time, and we have taken these steps to eliminate it, if necessary, and we have tried to evaluate it.

"We have built up *equipment which we are going to experiment with* to see whether there is a real material improvement when we put it in.

"Commissioner Hennock: I am just trying to find out where this testimony fits in. I am not sure whether I will be able to evaluate it properly. I do not expect to be able to. I just want to know what you are trying to prove, and what you are discussing, how it fits into the whole picture of your system.

"The Witness: This is, I believe, the first complete engineering analysis of our system that has been presented in the hearings, and I think that it covers just about every aspect of it.

"Commissioner Hennock: You discuss the defects and also the——

"The Witness: Possible defects, possible defects, or should I say defects which, at least, appear there on paper, and we are trying to evaluate them, and the mixed high, particularly, I think, has been questioned in this hearing. It has been misunderstood, and it has not been fully explained." (Tr. 7650-7651) (Emphasis supplied)

A few minutes later, Dr. Brown, who just said RCA was going to experiment, is talking of how RCA already has the means to eliminate crosstalk:

> "Commissioner Hennock: Well, frankly, I did not expect to understand you, as an engineer, but I just wondered where it would fit in here. What does this mean in the case? What do you want us to interpret by your testimony? Where does it fit in here? What are you trying to prove, in other words?
>
> [fol. 268] "The Witness: I am trying to show the steps that we can take to get rid of cross-talk, if it is necessary, for one thing.
>
> "Mr. Jensen, a week ago, and I think at the IRE, in his statement said that up to—I don't remember the exact figure—up to a megacycle we have purity of color; above that we have cross-talk.
>
> "I want to show that we have taken the steps and have means that if that cross-talk is serious we have the means of completely eliminating it.
>
> "I think that as to the matter of being able to reproduce the very high frequency components of the picture up in the neighborhood of 4 megacycles, by a sample dot interlace system, I want to show that even though the sampling frequency may be 3.6 or may be 2.6, if you will, that we can still reproduce frequencies up at 4 megacycles.
>
> "I might take a peep at my conclusions and see whether or not I am going to come out with that answer.
>
> "(Laughter.)" (Tr. 7656)

This is but another example how RCA brushes off serious problems un-field-tested rather than discussing them frankly in the record.

Just as in the case of mixed highs, the present state of the record with respect to this fundamental problem is completely conflicting. RCA claims 50% crosstalk between color signals, Dr. Boothroyd of Philco claims 33⅓%. Whatever is the extent of crosstalk, we may be almost positive that it degrades the color fidelity of the RCA system.

We have just completed a discussion of both the mixed highs principle and the crosstalk problem. Both of these

problems affect color fidelity of the RCA picture. While in the first demonstration October 10, 1949, of the RCA system, they showed practically no color pictures, the only improvement that has been made so far, according to this record, is some stability in the color reproduced by reason of the burst on the backporch of the synchronizing signal However, once the colors have been made stable, the RCA picture is still but a degraded color picture. The problem is particularly critical in the small areas of the picture, like lips, which never appear in natural color. It is also apparent in large areas on live pickup, when the movements of the body of the characters televised throw different shades of light or intensity of light upon the skin. On live pickup as the characters move around, as they naturally will in regular commercial broadcasting, once the head is nodded, the skin changes from a light tint to dark and unnatural grays or purplish hues.

In summary, upon examination of RCA color pictures (on the triphosphor tube or on the 3-tube receiving sets) it [fol. 269] may be observed upon close viewing that in the light tone color areas such as skin tones, there is a black crosshatching. There is also a color degradation in small areas which is visible at any viewing distance. Whether the degradation of color in the large areas particularly predominant in skintones during live programs is due to black and white crosshatching (mixed highs) or to contamination of one color signal by another (crosstalk) has not been determined. Color fidelity is degraded by both the use of mixed highs and the presence of crosstalk; nevertheless, the use of mixed highs and the selection of color by dots is claimed as an advantage of the RCA system. Even if RCA solves the problems created by crosstalk, the mixed high principle leaves the RCA system with a permanent form of color degradation. The theory that RCA has followed—that fine detail is not seen in color—their reliance on black and white crosshatching appears to tie their system permanently to degraded color in light tone areas, such as skintones, and in small areas, such as lips.[15]

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[15] Dr. Judd testified that in general the RCA system has had inferior color pictures as compared with CBS. He stated that on occasion RCA came up to the level of CBS. He further stated that on such occasion it was necessary

[fol. 270] III

It is RCA's position that all of the difficulties with the dot sequential system are merely problems of apparatus design. Since the studio equipment including the camera are basically the same as that used in 1946, it is appropriate to examine the 1946 record to determine the state of development of this equipment at that time.

In 1946 Dr. Kell said:

> "Cameras and transmitters for the simultaneous system are now being constructed. The camera being built will be suitable for both studio and outdoor use.
>
> "The transmitter will be completed and radio transmission with the simultaneous system will be started very soon.
>
> "A camera for the simultaneous system is now being constructed. The camera will be suitable for both studio and outdoor use." (Docket 7896, p. 696)

Much of the testimony in the present record has dealt with the apparatus problems which center around the RCA three-tube camera. Many of the witnesses explained that because the RCA tube camera is a three-tube camera it is subject to severe registration problems which have not as yet been conquered. It is believed that we all can agree that the registration problem at the camera must be solved if the dot sequential system is to become satisfactory. This is borne out on the record by the testimony of Dr. T. T. Goldsmith who upon cross-examination in the latter part of the hearing said:

> "Q: Will you please give to each of the systems, as I go down—will you indicate to me what you regard as the strong points and weak points of each of the systems? Suppose we start with RCA. First the element of registration.
>
> "A. The RCA color television system still has considerable doubt as to the registration problems being licked for commercial work.

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for Dr. Epstein, one of RCA's leading engineers, to be in attendance to adjust the RCA receiver. CBS in its brief raises the question of what kind of subject matter was televised during these tests.

"The RCA cameras as presently demonstrated yet is a triple optical head, *and there a very serious registration problem remains.*

"We believe there are developments in the mill which can overcome that particular registration problem, but we feel before it would be adopted commercially it should at least be experimented with to the extent of building practical working models to prove out the feasibility of such registration relief." (Goldsmith, Tr. p. 9921) (emphasis supplied)

[fol.271] The existence today of a registration problem in the RCA camera is all the more aggravated by the fact that RCA has testified and we know that the dot sequential system utilizes the same studio equipment as the simultaneous system utilized. Dr. Engstrom testified as follows:

"The color studio apparatus which we have installed in station WNBW at the Wardman Park Hotel in Washington and which will be used for demonstration during this proceeding will also be used for field testing on the RCA color system. This studio apparatus is 'simultaneous color' apparatus and has resulted from our work on the simultaneous system." (Tr. pp. 2677-2678)

Upon being pressed for improvements in the camera since 1946, Dr. Brown testified:

"Commissioner Jones: The thing that caused the question is that the color camera apparatus is the——

"The Witness: The same components used in the wide-band simultaneous system.

"Commissioner Jones: Yes, but it is different. You explained these modifications. I wanted to get the detail.

"The Witness: Yes, sir, that is right, the same components. Well, in our wide-band simultaneous system we use the dichroic mirrors, use the three tubes, you see, but we have learned better techniques. The tubes have been improved just as black and white camera tubes have been improved in the last three years. So I would not want to say it was the same color camera, you see. It is one using the same principles but using the improved tubes as they have come along, and im-

proved techniques on amplifiers and other circuits of the camera, just as they have been improved also in our commercial black and white cameras." (Brown, Tr. pp. 2816-2817).

But just as the camera is basically unchanged, so is RCA's attitude toward misregistration. Thus Dr. Engstrom testified as late as February 27, 1950, that registration at the camera was no problem:

"Item 29. Performance as to geometric scanning registry at receiver and pickup, both electrical and optical.

"The studio cameras which we now use in our color field tests are research models and do not include convenient flexibility for lens change and aperture control. We have evolved set-up routines, including scanning optical registry, which are effective in placing the cameras into operation. This we do with regular [fol. 272] studio personnel trained for black and white television operation but now having experience gained during our color field tests. The new field camera has a single lens for all three camera tubes, providing easy lens change and aperture control. We expect that a single lens will simplify the registry procedure.

"While registry adds steps to a set-up routine, *we have accomplished good registry in our studio performance. We believe that camera registry is practical for the RCA color television system, and are certain that it is not a limitation to the establishment of the system.* In our field tests we now have had over 1,000 studio camera hours of operation since early September, 1949.

"Mr. Salant: Mr. Chairman, may I ask a question there?

"Dr. Engstrom, could you tell me how many of those thousand studio hours were with live cameras, or were they all?

"The Witness: This is all live cameras; that is the number of hours that the cameras have been in operation.

"Mr. Salant: That excludes the hours in which you have used the flying spot?

"The Witness: Yes, it does; it excludes it.

"Mr. Salant: Yes.

"The Witness: The receivers which we have demonstrated to date have been of two types in so far as matters pertaining to registry are concerned. The first of these is the projection type where the three color images are projected simultaneously upon a single viewing screen. The other is the direct-view type wherein the images on the three picture tubes are viewed simultaneously through dichroic reflectors as a single image. Each of these arrangements involves matters of optical and electrical registry.

"In none of this work have we experienced any fundamental difficulty in obtaining proper optical registry of color images. Electrical registration achieved in these arrangements has been satisfactory and give no indication of being a system limitation. We are now convinced that these matters are fundamentally feasible and practical. Their satisfactory attainment involves no more than normal apparatus considerations." (Tr. pp. 6102-6103) (emphasis supplied).

[fol. 273] More important yet is the fact that just as in 1946, so in 1949-50 RCA did not explain how it could develop the 3-tube camera which causes the misregistration into a one-tube camera and yet retain mixed highs, an essential element of its system. For mixed highs require a simultaneous camera while only a one-tube camera is required for the sequential system of color TV.

We must therefore come to the conclusion that it is extremely doubtful whether RCA, which has had five years to lick the problem, will ever lick it. Dr. Goldsmith says it is today still very serious.

Another problem which RCA cannot seem to conquer is construction of outdoor pickup equipment. This problem is, of course, related to the registration problem in the camera. The permissible tolerances are so critical that completely stationary equipment is all that has been built up to this time.

But back in 1946 Mr. Kell, as we have pointed out, said outdoor pickup was then being built. None, of course, was offered in the 1946 hearing. On September 30, 1949—four

years later—Dr. Engstrom announced RCA was still building this equipment:

> "We have started development of a field type color camera and associated apparatus. This we expect will be ready next spring and will then be added to the field test set-up. This field camera will use a new camera tube which will greatly reduce the size of the camera itself. A mock-up of this camera and an operating sample of the camera tube will be available for display during our demonstration on October 10." (Tr. p. 2718)

And the same day he announced this equipment would be field tested:

> "We then will move receivers into the area, will test them, will move them around, we will establish programming tests, so that we learn how to produce programs for color, what the flexibility is in producing programs for color, and then, as I indicated earlier in my testimony, we will move into the area, when completed, field type equipment, so that we may go outdoors and try programming from outdoor scenes." (Tr. p. 2747)

Dr. Brown in his testimony in the beginning of the hearing minimized the problem RCA has had to face in this regard.

> "Commissioner Jones: Yes, sir. It seems relatively simple, but the reason I ask, I understand you did not have any outside camera equipment, and I wondered whether the difficulty was the size or what.
>
> [fol. 274] "The Witness: No, sir. The camera itself. You see, you know the engineers will begin working with this thing, and it is the language you have to check us up on.
>
> "The camera itself is not the problem as far as outside equipment, the other things. The signal coming out of the cameras has been amplified. You have to have synchronizing generators, you seek, and we have equipment that represents the terminal equipment that is put in a fixed position in the television studio. And then you have to develop and construct a suitcase equipment to take out with the camera to accompany

the camera—the synchronizing generators, the circuits, and power supplies, and all of those things that give you deflection in these camera tubes." (Tr. p. 2815)

But a moment later Dr. Brown confessed to the true state of the situation; he didn't even know what would be inside the field pickup.

"Commissioner Jones: I am sorry. I will try to say again what I had in mind. I did not mean to infer you use the same outright physical equipment you used in the simultaneous system. What I was trying to do was to get the picture so those presently broadcasting black and white in all of its problems, remote pickup, studio programs, and chain programs, and so forth, just what changes now to adopt your system would have to be made, and what the problems are: How big the equipment is; what weight it has; and so forth.

"Could you embellish it that way?

"The Witness: Heavens, no. I wouldn't have the faintest idea how to tell how big it is and how heavy it is going to be, and that sort of thing, because I don't regard this outside pickup camera as a research program. It is a matter of having time to do these things, to get them built.

"And if we had thought—well, if your notice of hearing had been out three months sooner, maybe we would have had it. I don't know. You just can't do everything in the laboratory, and we chose to do the things in preparation for our demon trations that we though- would be significant. And I know that I myself did not feel that to prove the principles of the system we would be called to have remote pickup equipment.

"Now, of course, if we are going to try to prove that, that we have got a system, got the stuff on the shelf, if we have to demonstrate a remote camera—and we will have it and expect to have it early in the spring." (Tr. pp. 2817-2818)

[fol. 275] But February, 1950 came and still the outdoor pickup was in the laboratory. However, there were signs

that it was coming along and the problem was now getting easier. Dr. Engstrom testified:

"Portable Field Pick-Up Equipment:

"In our progress report of December 30, 1949, to the Commission, we indicated progress in the development of portable camera equipment which might be used for remote color pick-ups.

"At the time of our October 10, 1949, demonstration we showed a sample of a small pick-up tube, which we have called the Vidicon, and mock-up of a small field camera. This mock-up represented a goal toward which we are directing our efforts on portable color field pick-up equipment. However, at the present stage of development, it seems best to use standard components and circuits and to make provision for a lens-turret and an electronic view finder. Accordingly, the field camera which we now have completed is housed in an ordinary black-and-white field camera case. The compression in size of this extent is made possible by using three Vidicon tubes similar to the one shown on October 10th.

"Electrical testing of the circuits of this camera, and associated apparatus is underway. When tested, this field camera will first be used in Princeton in color vs. color tests in connection with our studies of co-channel and adjacent-channel interference on the RCA color system. Upon the completion of these measurements we shall use the field camera in New York to furnish a color signal for WNBT, New York. We shall then take field measurements on interference between WNBT, New York and WNBW, Washington, both on Channel 4 and each using an RCA system color signal.

"Following these field tests, we plan to bring the field camera chain to Washington for use in our color television field test.

"Field Test Activities:—

"The Chairman: Mr. Engstrom, at what date do you expect to conduct these co-channel and adjacent-channel tests?

"The Witness: We are hoping to do that during the month of March. I believe within about a week we hope to get the work started.

"The Chairman: Go ahead.

[fol. 276] "Commissioner Jones: Is this a necessary component to the successful operation of your system?

"The Witness: You mean a field——

"Commissioner Jones: The camera, the field camera, and so forth?

"The Witness: We did not feel so in the first place, Commissioner, because there is nothing about this system which is limiting for the kind of camera we use; only that the cameras we built first were suitable for indoor use, first, and tied by cables to a control room in the studio; but obviously we will want to make observations with field cameras.

"Commissioner Jones: What I am trying to get at is if you do not develop this camera to your satisfaction, and you just have the conventional cameras, you do not recommend holding up the adoption of standards on your system because of the failure of the development as your expected of the new camera?

"The Witness: No, but we don't expect failure." (Tr. pp. 6034-6036)

However, as late as May 9, 1950, when the record was about to be closed RCA not only had not field tested an outdoor pickup but had introduced nothing into the record on this score. RCA did make an estimate of the cost of such equipment, it said (Exhibit 378A):

> "In respect of field cameras, it is believed the cost will be approximately the same as for studio cameras, subject to the same potential reductions in cost."

No further information with respect to field cameras was supplied. CBS objected to the introduction of this cost estimate. The record is as follows:

> "Mr. Salant: Then I do have one other question.
>
> "The second paragraph of 378-A, I think, is objectionable simply because nobody has any basis for making a judgment of its accuracy.
>
> "We have not seen a field camera; we do not know what goes on inside or outside of it, and we have this

bare statement, that a field camera, of course, is necessary for the operation of a station; but we have no more than this second paragraph; I do not think it is enough.

[fol. 277] "Mr. Heffernan: Well, in respect to that, Mr. Chairman, it is an estimate given by RCA of the price at which apparatus would sell, and at this stage of the art, we submit that that is perfectly reasonable and normal to do. It does not differ in principle from other estimates given here throughout the case.

"Mr. Salant: In the case of estimates for other pieces of equipment, one has seen them and one knows what is inside them; one knows how they work. The field camera, so far as the record is concerned, is a complete unknown.

"The Chairman: I think with the discussion that there has been about it, we will let it stay in." (Tr. pp. 11016-11017)

Nothing further with respect to field equipment was introduced by RCA during the remainder of the hearing.

Because of its critical nature grave problems exist with respect to the development of a field camera for the RCA system. It is to be noted that the evidence of a satisfactory field camera is of essential importance to any color system. Commissioner Sterling expressly asked Donald Fink whether the Commission could gamble with a system that had a satisfactory indoor pickup but had not as yet developed an outdoor pickup. Mr. Fink answered that the Commission could not take a chance with such a system because an outdoor pickup was essential. (Tr. p. 2142). It will further be recalled that during the 1946 hearing much ado was made with respect to the failure of CBS to demonstrate the outdoor pickup that it claimed it had built. The Commission referred to the failure to demonstrate this equipment in its 1947 color decision.

It is of the utmost importance to recognize that this very same camera with all the attendant problems described above is exactly the same camera borrowed from the RCA simultaneous system. In other words, if RCA has been working on its outdoor pickup for five years, an assumption that it can't put together anything good enough to show the Commission is justified. If it has not been working on this problem to improve registration, there is little

likelihood that it is interested in color TV with good registration.

Dr. Engstrom testified that registration was not a system problem but one of apparatus design. In his opinion it was licked in 1946. He said:

> "Our analysis, and the review, continued, and those systems which looked as if they might remove the limitations we found in our sequential setup, all required the registration of more than one image at the receiver.
>
> [fol. 278] "We moved in this direction with some hesitation, because a number of years ago we set up that sort of a system; but our tools were not sharp enough; we did not do the job to our satisfaction.
>
> "However, since our analysis indicated that we might move on that road now, we made those tests to determine what our problems would be, and we learned that as a result of the things we had done during that interval of five or six years, we had improved the situation to the extent that the problems were less severe; they are of such a character that they can come within the scope of practical design limitations. So, we then moved in the direction of thinking about the complete system." (Docket 7896, p. 1130)

However, at the demonstrations in 1946, Dr. Goldmark saw misregistration:

> "Dr. Goldmark: I would like for the members of the Commission to step up and observe—I would like to point out quite serious color fringing, which may be partly electrical. I would like to point out the color fringes which apparently are partly electrical, and due to electrical lack of registration and partly due to lack of geometrical registration on both receivers, both color receivers." (Docket 7896, p. 1217)

And so did Mr. Plotkin:

> "Mr. Plotkin: Mr. Engstrom, I noticed that some of the film sequences that along the edges of some of the figures there seemed to be some green color. Was that the color mixture or was it maybe a green ghost or what?" (Docket 7896, p. 1147)

Dr. Engstrom's comment in reply to Mr. Plotkin's observation was typical of RCA's attitude toward misregistration in 1946 and in 1949-to-:

> "The Witness: I think that is just one of the problems we have left ahead of us.
>
> "I am going to say, and at the same time ask for verification from Mr. Kell—I am sure that what you saw was not misregistration, but lack of ability so far to handle all the little niceties of this color situation. Is that correct, Mr. Kell?
>
> "Mr. Kell: That is right; and I think that we can see that a little more clearly when we get some stationary slides that will stay put and we can get-up and look at them carefully." (Docket 7896, p. 1147)[16]

[fol. 279] If it be claimed that the misregistration was due in part to the receiver problem, we must consider the testimony of Mr. Kell that receiver misregistration probably would not be objectionable. He said:

> "The registration requirements are similar to those existing in color printing and some kinds of color photography. Ideally, the three rasters should be identical and properly positioned within a fraction of the width of a scanning line. Practically, a considerable amount of misregistration may be present without being objectionable." (Docket 7896, p. 703)

A little later Mr. Kell testified further with respect to registration in the receiver:

> "Six, Image registration: In the sequential system there is a registration problem of the three color images caused by regulation of the voltage supply for the kinescope.
>
> "In the simultaneous system the problem of initially registering the three color images on the screen is substantial.
>
> "However, by using a single vertical and a single horizontal deflecting circuit for the three kinescopes,

[16] It is to be noted that Mr. Kell felt there would be less misregistration when the subject matter was being televised by a flying spot scanner.

the problem has been proven to be less difficult than was expected.

"Even with the first developmental kinescopes and deflecting yokes, good registration has already been obtained.

"With mass production of components by machines and jigs where uniformity occurs naturally, excellent registration will be obtained and maintained without serious difficulty; based on our experience that we have had, we have no question of the practicability of registering the three images." (Docket 7896, p. 726)

From the demonstrations in this hearing it is of course clear that in 1950 RCA had still not solved the registration problem in a three-tube receiver. And whatever may be the effect of the tricolor tube on the receiver registration problem in the RCA system, RCA in 1950 still has the same camera problems it had in 1946.

[fol. 280] IV

In evaluating the engineering representations made during this hearing, the Commission must recognize the motives which may possibly lie behind them. Examination of the record of the hearing on color in 1946-47 makes clear what we mean. In 1946 RCA admittedly brought out of its laboratories a simultaneous color system because its prime competitor, CBS, proposed a color system which involved opening up the UHF. While it claimed the system had been tested so far as the basic principles were involved, it admitted that the details of apparatus still had to be worked out. RCA must have recognized that merely holding out the hope of a simultaneous system would not be enough to stop color in 1947. Therefore, RCA, together with the organized industry (RMA and its members), offered the Commission a concrete time table which it was claimed would bring color to the American people via a fully developed commercial simultaneous system by the middle of 1951 at the latest. In addition, it was claimed that color would be started much before this. It was stated that 18 months from the time of the Commission's decision rejecting the CBS proposal, standards for the simultaneous system would already have been set. It was stated that within 12 months from the Commission's decision denying

the CBS petition, full field testing would be in operation with two transmitters. The testimony, which attempted to lay a picture of reality behind the simultaneous paper system, was given by Dr. Engstrom as a witness for the RMA. He said:

"The third question before Committee 2: How long will it take to establish basic standards for such a compatible system, and to develop that system to provide a broadcasting service comparable with the present black-and-white service?" (Docket 7896, pp. 1324-1325)

"The Committee took as the basis for the estimates in answer to Question 3 the assumption that the present FCC hearing would close without the establishment of any standards for color television. It was also assumed that work would then proceed expeditiously on the development and field testing of the simultaneous system leading to industry agreement on standards and then to production of apparatus.

"A review of the opinions of those present indicated that field testing could start in six months, and be in full-scale operation in 12 months with two or more field-test transmitters.

"Field testing would then continue actively until standards are agreed upon and then taper off until start of production and commercial programs.

"This review also indicated that the consideration of standards could start immediately upon a decision from this hearing, with agreement to be expected in 18 months.

"The estimates of time assume that development work would continue from zero year—zero year being the time the decision to establish no standards is reached at this hearing—until agreement on standards [fol. 281] is reached 18 months from zero year. The slant line of the charts to which we will refer later for each item of the simultaneous system is intended to indicate this. The estimates further assume that until standards are agreed upon orders will not be placed for apparatus and commercial licenses will not be issued to broadcasters. (In the estimates for the sequential system this time for the establishment of standards is zero year and for the simultaneous sys-

tem, zero year plus 18 months.)" (Docket 7896, pp. 1328-1329)

Since this testimony was given in behalf of RMA, the Chairman put questions to Dr. Engstrom as an RCA witness. This testimony established the agreement of RCA with the statements of Dr. Engstrom as an RMA witness.

"I think perhaps it might be easier for you to answer from the standpoint of your own company.

"Your own company, as indicated, would have a simultaneous receiver ready for retail sales six months later than it could have a sequential system ready; is that right?

"The Witness: Yes.

"The Chairman: You start a year and a half later, so somewhere along the line you pick up a year.

"The Witness: I think, Mr. Chairman, that the process which I shall describe is probably one of the reasons why some of these charts come out the way they do.

"We do not in fact, speaking now of the RCA estimates, start a year and a half later, because all during this period up to the time that standards might be agreed upon we will be in the process of developing radio circuits, the intermediate frequency circuits, and many of the components of the receiver.

"We, I think in common with some others, *do not today have satisfactory designs for the head end of a receiver*, either *as to certainty of stability* and *certainly not as to avoiding oscillator radiation.*

"On the estimates which are indicated here, *all but one manufacturer took into account doing the things that will be determined necessary to reduce oscillator radiation* of a satisfactorily low level, and it is those things which take time, so there is little loss during that particular period when standards might be in the process of determination for the simultaneous system." (Docket 7896, p. 1333) (emphasis supplied)

It must be remembered at this point that CBS had substantially field tested its system and had proposed standards for immediate adoption. RCA in the earlier stages of the hearing was making no distinction between equipment

[fol. 282] development problems and the Commission's duty of setting standards for commercial operation of color broadcasting. It is obvious that since Columbia *and* proposed standards for its system that RCA's efforts were to show that even if the Commission waited 18 months the adoption of standards for the simultaneous system, there would be no time lost for the initiation of color broadcasting because the time for development of commercial equipments far outdistanced the time required for the Commission to set standards. Dr. Engstrom, in drawing this distinction, testified as follows:

"The Chairman: I think I understand, but let me try once more.

"*Taking just the simultaneous receiver, there is a certain amount of work that has to be done before you can get a simultaneous receiver ready to sell.*

"The Witness: Yes.

"The Chairman: Now, let us say that is, according to your estimate, a 3½ year period.

"Now, standards could come at any point along that line. If standards come now for the simultaneous receiver you would still have 3½ years' work. If standards come a year from now, you would still have 3½ years' work; is that right?

"The Witness: I think that is a theoretical case, yes; but if we could have standards today on the simultaneous system, then it is not likely that it would take all of the 3½ years, because in order to decide upon standards, we must have decided upon some of the components in some of the designs.

"The Chairman: That is what I am trying to get at. That element in included?

"The Witness: That element is included, and the production time I suppose in all of these estimates—that is, the time between the issuance of drawings in the factory and the first delivery of apparatus—is in all cases probably much less than the indicated time here, being in the order of probably a year or possibly 18 months and the additional time of the estimates of preparation to be in a position to issue designs to the factories for production." (Docket 7896, pp. 1334-1335) (emphasis supplied)

Dr. Engstrom upon cross-examination re-emphasized all of the work that would be done on the simultaneous system if the Commission did not make an immediate decision on the field sequential color system.

[fol. 283] "By Mr. Brauner:

"Q. Mr. Engstrom, how was the figure of 18 months for the establishment of standards for the simultaneous system developed? Was that an average figure?

"A. It was done in discussion, Mr. Brauner. Before that figure was even reviewed, the figures which preceded it in the report were set up that it would be six months before a field test would be initiated that could be shared with others in the industry, that then it would be 12 months before that field test system would be adequate from the point of view of let us say all kinds of programs and ability to transmit signals so that others could share in the transmission, and looking back at the experience that has been had in the development of black and white standards and the review of those standards during 1944, and the work which has taken place during the past year in a consideration of color, those people who were present believed that 18 months was a proper estimate to make, that they could come to an agreement in 18 months.

"The Chairman: How much time would you leave for hearings? (Laughter)

"The Witness: I thought, Mr. Chairman, that question would be asked, and we discussed it from this point of view.

"In the case of the sequential system, it was zero time, because the Commission in its report on this hearing would decide the matter, and therefore zero time was allowed in the simultaneous system.

"On the other hand, there were expressions from some of those present that the consideration by the Commission could obviously be started before the 18 months' period was completed." (Docket 7896, pp. 1359-1360)

Dr. Jolliffe at the earlier portion of the hearing had testified, however, that it would be a matter of approximately 4 years before commercial standards could be set for the

simultaneous system. This was, of course, inconsistent with the later testimony of Dr. Engstrom that it would take only 18 months to set such standards. Dr. Engstrom, upon cross-examination, tried to wash away the inconsistency.

"By Mr. Brauner:

"Q. Mr. Engstrom, has your company advanced its time table as to the date on which standards could be adopted for a simultaneous system? It is my recollection that Dr. Jolliffe testified it would be approximately four and a half years.

"A. Not before standards could be adopted—before a service could be rendered, if I remember correctly.

[fol. 284] "Commissioner Jett: Dr. Joliffe is present and can correct me if I am wrong, but it is my recollection that he testified it would be four years before we could be able to establish standards for color television.

"The Chairman: Do you have the reference?

"By Mr. Brauner:

"Q. On page 674, Dr. Jolliffe said:

'In my opinion, to design, build, install and operate that equipment it will be a matter of approximately four years before you would get all the information that should be gotten, before you take the steps to finally approve commercial standards.'

"Commissioner Jett: Of course, Dr. Jolliffe made that statement before we were very far along in this hearing.

"The Witness: I think, Mr. Brauner, I would rather answer it from another point of view.

"In December of 1945, when we made our demonstration of the sequential, we estimated at that time that was of the order of five years before a color system could be made commercially equivalent to black and white at that time.

"We are now some 15 months advanced, and whether the industry has made 15 months of progress might be argued, of course, but if you take our original estimate, it would be something then in the order of four years from today.

"Now, the estimates made on a particular date five years in advance are subject to certain tolerance. I don't think basically we have changed our point of view on that, because the estimates that are in this report, provided by us come within the sphere of that earlier estimate and the estimates which we have made since then." (Docket 7896, pp. 1361-1362)

These lengthy excerpts establish beyond doubt that RCA and the RMA made a full fledged commitment to the Commission to field test and set standards for the simultaneous system within 18 months from the time when the Commissions 1947 decision rejected the CBS proposal. We know as a matter of fact that despite Dr. Jolliffe's guarantee that the simultaneous system would work, there has never even been a satisfactory radio broadcast of that system.

Even when the fundamental defects in the simultaneous system became known to RCA, RCA took no steps to inform the Commission that it had dropped the system. The industry must never have field tested it because not one of them made a progress report to the Commission that their field tests on the system had proven it impractical. Even [fol. 285] the head of the RMA engineering department, the man who was former head of the NTSC and RTPB and the present head of the current NTSC, Dr. W. G. R. Baker, never formally learned that the simultaneous system had been dropped. Dr. Baker testified as follows:

"The Witness: I would like to add this thought, and it may or may not be important. If I remember rightly, and this thing is pretty hazy to me, a lot of work was done on simaltaneous system, and it was found out that it was not the system to give a good system of color because of the transmission of the three simultaneous colors at the same time. Some place in there, I don't know just when it is, but I have the hazy recollection that the simultaneous system on further development showed negative." (Tr. p. 9758)

"Q. Now if this were a commitment in 1947 that consideration of standards for simultaneous system could start with agreement to be expected in 18 months, RMA could have set up an NTSC to try to get that agreement?

"A. They could, but I think what actually happened was RCA carried on the simultaneous system and found it was negative and therefore dropped it.

"Q. So what happened is RMA, having made that statement, whether it is a commitment or not, and then turned it over not to an industry group but to RCA and nothing happened, is that correct?

"A. Nothing happened because the results were negative.

"Q. The results were negative?

"A. Yes.

"Q. There were no standards, is that correct?

"A. The system didn't work out.

"Q. There were no standards, is that correct?

"A. There were no standards because the system proved faulty.

"Q. When did you first hear that the results were negative, Dr. Baker?

"A. I don't really know. I read that some place and I don't know. As I keep talking to you, my memory refreshes itself. I am sure that is what happened.

"Q. You read it some place?

"A. Yes, I think so.

[fol. 286] "Q. You, as the head of the RMA Television Engineering Department, didn't bother yourself checking, you had to read it somewhere?

"A. Yes, sure, that is right." (Tr. pp. 9760-9761)

Further proof *the* the lack of good faith of RCA, irrespective of the failure of the system, is a review of the promises made to develop equipments at the time the simultaneous system was held out as a bait to the Commission to adopt no color standards. This is all the more significant since even if propagation caused the downfall of the simultaneous system, the same studio equipment is now offered in connection with the dot sequential system. Inasmuch as the present RCA dot sequential system utilizes the same equipments as the simultaneous system did in 1946, and since RCA did not have any better developed equipment at the time of the present hearing, one can conclude that they learned shortly after the March 1947 decision rejecting sequential color that the simultaneous system was impractical and unsound. Had they carried out their promises over any extensive period of time after the March 1947 decision,

it would appear that they would have made progress in the commercial development of the three-tube or the tri-phospher tube for the receiver. We are therefore faced with one or both of two alternatives. RCA, with the largest electronic laboratory in the world, having found out that the simultaneous system would not work, delayed commercial color with inactivity in the face of the Commission's request for further color experimentation. The other alternative, which may be in addition to the first, is that RCA was not able to develop practical studio apparatus for the kind of system it fostered in both 1946-47 and 1949-50.

What we have demonstrated is that when the field sequential system was proposed by CBS in 1946, RCA offered as a still better system its own simultaneous system. It admitted, however, that its system, like the CBS system, needed further field testing. It emphasized, however, the very comprehensive nature that such field tests should take. While RCA may well have been on sound engineering grounds in advocating such comprehensive field tests, it so happened that as a result of this position on field tests color could always be put off for several years. Thus, in 1946, Dr. Jolliffe testified:

> "The Witness: My definition of an adequate field test is one in which you use a full-scale transmitter and have substantially commercial receivers installed in homes and a substantial number of homes and carry on a program service which is illustrative of a program service which might be used as a commercial service, and have that operate for a sufficiently long period of time that you can get the results of people who are observing these receivers and really get the reaction.
>
> "In my opinion, to design, build, install and operate that equipment it will be a matter of approximately four years before you would get all the information that should be gotten, before you take the steps to finally approve commercial standards." (Docket 7896, pp. 673-674)

[fol. 287] In 1949 a similar pattern was repeated. Once again, although this time not completely voluntarily, CBS offered the Commission a field sequential system which it claimed was ready for adoption, once final field tests had been completed. RCA again came out of its laboratory, ad-

mittedly prematurely, with a color system. This time it was a dot sequential system. RCA told the Commission its system was "developed". Its press releases indicated that RCA now had a full-blown color television system. Its first written comments filed with the Commission represented the dot sequential system as providing a superb color broadcast service; it certainly appeared that this system was an electronic ideal made real. However, as in 1946, it early became apparent that RCA was in no hurry for the adoption of color standards. It repeated its statements of 1946 with respect to the nature for long and comprehensive field tests before any color system, whether it be RCA's or CBS's should be adopted. By letter dated September 13, 1949 (Exhibit 208), Dr. Jolliffe wrote the Acting Chairman of the Commission:

> "The Radio Corporation of America believes that any system of television should be thoroughly tested in the field under conditions approximating as nearly as possible regular commercial operations. This applies equally to program production, transmitter operation, and *receiver operation in the home.*" (emphasis supplied)

In commenting on this letter, Dr. Engstrom stated:

> "I think that it is in keeping with my testimony, Commissioner, that until the system has been set up, and been operated in the form simulating as nearly as possible the way in which it will be set up after it is authorized as a service, it is unwise to freeze the standards to the extent that allocations are made and manufacturers produce equipment for the public." (Tr. p. 2765)

The RMA, of course, supported RCA's philosophy by admonition to the Commission to make haste slowly. One of its committees set out the requirement for 30 individual field tests.

RCA did not object to any of the 30 categories of field testing suggested by the RMA. Specifically, in the hearings, the chronology of RCA's attitude toward field testing was unfolded in the record as follows: At the very beginning RCA stated that final field testing of apparatus will not take place until the standards "are fairly well

known" (Tr. p. 2769). Testifying on September 30, 1949 (Tr. p. 2805), Dr. Engstrom stated that he believed that standards might be written after six months of field testing. It was not clear, however, exactly how these standards would be written. Dr. Engstrom testified that final standards should not be set; he hinted at an NTSC stating that the Commission should not set final standards without the cooperation of the industry (Tr. pp. 2801-2804).

As the hearing went on, under the lash of good CBS performance, on February 27, 1950, Dr. Engstrom testified that RCA was now ready to discuss the formulation of standards (Tr. pp. 6124-6125). Dr. Engstrom stated, how-
[fol. 288] ever, that while RCA was ready to lay down "the elements for standards", "there are certain items on which we do not have all of the information" (Tr. pp. 6124-6125). Dr. Engstrom stated that by the time six-month period elapsed from September 27, 1949, RCA would have had its tube and it would be in a position to discuss standards (Tr. p. 6130). Later that day, he stated that he had no mental reservations on the setting of standards for a color system "now" (Tr. p. 6153). On further questioning he said he was ready to discuss standards with the staff immediately, that it was not necessary to wait for the tube (Tr. p. 6163, 10874).

On April 4, 1950, Dr. Brown testified that the RCA system was ready for the establishment of basic standards (Tr. p. 7821). But again testimony was offered about field testing which would follow the adoption of basic standards (Tr. pp. 7823-7824). It was stated that such field testing would take six months and that during that period even though standards were adopted, commercial operation would not yet begin.

By May 3, 1950, it was apparent that the hearing would not fizzle out on a note of despair for color. Too many people were saying color was here now. Even the industry took the cue; with the demonstration of the triphosphor tube, the trade press dropped discussion of color as a phony issue to hold up television and heralded the advent of color. On May 3, 1950, General Sarnoff testified that the RCA system was ready for final standards (Tr. pp. 10046, 10058, 10062-10063). General Sarnoff stated that further field testing was not necessary. He was not sure whether or not numerical values for the standards had already been sup-

plied for the record (Tr. p. 10064) but stated that if they had not been furnished they would be supplied. Later on he conceded that numerical standards had not been supplied for the record (Tr. p. 10602). On his return to the stand, Dr. Brown supplied numerical values for the standards (Tr. p. 10721). Dr. Engstrom upon his return to the stand reiterated that the RCA system was ready (Tr. pp. 10874-10875).

Accordingly, we had here a clear representation by the RCA that as a matter of engineering, its system had been sufficiently field tested to be ready for full commercial standardization. Such a representation by what is probably the world's foremost electronics laboratory would, under ordinary circumstances, be entitled to great weight. However, it is believed that just as in 1946 and 1947 RCA made definite claims for the simultaneous system, so again in the present record the claim that the dot sequential system is now ready for standardization has been made solely because it wishes to head off adoption of the field sequential system.

The representations by RCA both through its lay and engineering witnesses are very significant because, without a shadow of a doubt, the RCA system is, from an engineering point of view, not ready for standardization. The RCA system is a system which makes use of several new concepts, such as dot interlace and mixed highs, in addition to time multiplex, none of which had ever been seriously field tested. Serious questions have been presented with respect to networking of the RCA system and with respect to the system's susceptibility to interference. Actually the field tests of RCA have included no networking. There has been no field testing of remote pickup equipment. [fol. 289] In any event, it would appear clear that receivers in the hands of the public, no matter how few, should at least meet the test of successful operation.[17] It is to be noted

[17] It must be remembered that before the standards were actually adopted for black and white in 1941, the Radio Corporation of America put on extensive campaigns to demonstrate black and white television to the public. Currently RCA has demonstrated its system over WNBW, but there has been no promotion of any kind so that the people may see the effect of their system in color. There has been

that Paragraph 160 of the RCA proposed findings states that the receiver- which were in the hands of FCC personnel were laboratory models. If this is so, no commercial models of RCA receivers have been field tested. It is still more significant that Dr. Engstrom admitted that the critical tuning on these receivers should be field tested. (Tr. pp. 10864-10865). Certainly a receiver which must be attended by one of RCA's top engineers, such as was the case when the Bureau of Standards operated the RCA receiver, has not met the test of simulated commercial operation (Tr. p. 11187). The attitude of RCA with respect to the field testing of its receivers is best summed up by the testimony of General Sarnoff who, when asked: "Do you think RCA has sufficiently shown the performance of its receivers in the home as a practical home television set?", replied, "I am assuming that the Commission has a little imagination in addition to some information, and that when they look at a set they can tell it as well as you can anyway, as to whether it is sufficient or whether it is not." (Tr. p. 10395)

In the face of the record with respect to the extent to which the RCA system has been field tested, the most recent RCA position is summed up in its brief that: These tests and demonstrations show that the RCA color television system is ready for immediate standardization and no further field testing is required in order for the Commission to set standards based on the RCA system.

The only conclusion that can be reached is that at the beginning of this hearing RCA truthfully admitted that its system needed more work before the Commission would be in a position to standardize upon it, since the industry was almost solidly opposed to the CBS system and they felt

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no promotion of viewing their color signals in color, but rather the entire promotion has been toward viewing their system in black and white. Each time the color signals are broadcast the emphasis is made upon black and white reception. It can be said that they have not promoted viewing their color system in color because they did not have sets with the tri-phosphor tube, but RCA contended throughout this hearing until General Sarnoff took the stand that the three-tube receivers were meant for commercial sale. They certainly could have been used for demonstration purposes.

that there was no imminency of its being adopted. However, when it appeared that there was a fair chance that the CBS system might be adopted, RCA attempted to hold off such Commission action with the engineering bludgeon that the dot sequential system, too, was ready for commercial standardization.

[fol. 290] Such shifting of engineering representations in order to further RCA's personal interests renders questionable in great degree all of the other engineering promises it has made on this record. Inasmuch as the industry committee RMA by its silence acceded to this shift in RCA position with reference to the necessity for field testing, to the same degree its engineering representations are also rendered questionable. For it is one thing for an organization to take a policy position, such as being for or against color policywise, in furtherance of its own interests. It is quite another thing for an organization, through the mouths of its best engineers, to make engineering representations for the sole purpose of favoring its own interests. In the case of the engineering representation that the RCA system is presently ready for standardization, it is believed the RCA tactics with respect to color are made clear. RCA has one genuine purpose and that *was* to defeat color.

(Here follow 3 Photolithographs, side folios 291, 292, 293-294)

EXHIBIT "C" Complaint

54313-9/50

FCC 50-1065

FEDERAL COMMUNICATIONS COMMISSION
Washington 25, D. C.

In the Matters of	)	
Amendment of Section 3.606 of the Commission's Rules and Regulations.	)	Docket Nos. 8736 and 8975
Amendment of the Commission's Rules, Regulations and Engineering Standards Concerning the Television Broadcast Service	)	Docket No. 9175
Utilization of Frequencies in the Band 470 to 890 Mcs. for Television Broadcasting.	)	Docket No. 8976

SECOND NOTICE OF FURTHER PROPOSED RULE MAKING

1. Notice is hereby given of further proposed rule making in the above-entitled matters.

2. The Commission proposes to amend Part 3, Subpart E, of its Rules and Regulations ("Rules Governing Television Broadcast Stations") and Sections 1 and 2 of its Standards of Good Engineering Practice Concerning Television Broadcast Stations, in accordance with the "First Report of the Commission (Color Television Issues)" (FCC 50-1064) issued in these proceedings simultaneously with this Notice. Because of the size of the Report, it is not attached to this Notice, but copies of the Report are available on request at the offices of the Commission. However, for information of interested persons, paragraph 151 of that Report, relative to the adoption of bracket standards, is quoted, as follows:

> "151. In order to accomplish this purpose, the Commission simultaneously with the release of this Report is issuing a Notice of Proposed Rule Making providing for bracket standards in the present monochrome system. These bracket standards provide for a television composite video signal of substantially the type and proportion now employed in monochrome, but with the number of lines variable from 15,000 to 32,000 per second, and number of fields ranging from 50 to 150 per second. 33/ Receivers built to incorporate such bracket standards would

33/ The Notice provides that if the brackets are adopted, television broadcasters will continue, until further order of the Commission, to broadcast in accordance with present standards--15,750 lines per second and 60 fields per second